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Vol. XVII, No. 8

JUNE, 1958

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In This Issue:

Operation Phototrack

Solar Radio Astronomy in Texas

Observing Plans for October's Eclipse — I

The Densities of Gaseous Nebulae

Some Satellite Studies

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Sky and TELESCOPE

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Operation Phototrack

A PROGRAM for volunteer photographic observations of artificial satellites has been formally endorsed by the U. S. National Committee for the IGY. Called *Phototrack,* its aim is to provide photographic records of satellite passages that will supplement observations by the world network of high-precision Baker-Nunn cameras operated by the Smithsonian Astrophysical Observatory.

The new program is actively supported by the Society of Photographic Scientists and Engineers. The requirement is for negatives of at least 4 by 5 inches, taken with lenses of 5-inch focal length or longer. The trace of the satellite against the background of star trails is to contain two gaps or displacements timed to an accuracy of 1/10 second.

Although the determination of a satellite's position *along* its path is limited by the accuracy of timing, the position of the path itself can be determined to within 50 yards from Phototrack negatives. This will aid studies of the size and shape of the earth and the effects of air drag on the moonlet.

Fast lenses, some of the new very sensitive emulsions, and forced development are required to record most of the faint satellites now in orbit, such as the six-inch sphere of Vanguard I (1958β2). For such objects, photographers need to know in advance the optimum camera orientation and, in some cases, precisely when to begin, interrupt, and end the exposure for an object they cannot observe visually.

A Phototrack observer has to supply his camera's latitude and longitude within one foot, as well as his elevation above sea level. Maps showing triangulation markers and bench marks may be obtained from the U. S. Geological Survey, and members of the American Congress on Surveying and Mapping have been asked to help.

Short-wave time signals from Station WWV are essential to timing the photographic trail breaks. In the IGY *Bulletin,* March, 1958, several methods for recording time are suggested, including photography of an accurate clock by another camera and photoflash. Further details and report forms may be requested from Mr. N. Goodwin, SPSE, 826 Connecticut Ave. N.W., Washington 6, D. C.

The Phototrack project is receiving orbital predictions by means of the Civil Air Patrol radio network, headed by Station VPZ, which has been broadcasting satellite observing data every weekday evening since November 26th. Communications arrangements are being improved to serve simultaneously the needs of Phototrack, MOONWATCH, Moonbeam, ionospheric stations, and interested newspapers within the United States.

The 28-foot dish and fiberglass tripod carries the antenna system, one of the most elaborate ever placed on such a paraboloid; it was designed by Henry Jasik. All illustrations with this article are from the Radio Astronomy Station of Harvard Observatory.

Solar Radio Astronomy in Texas

ALAN MAXWELL
Radio Astronomy Station
Harvard College Observatory

THE FIRST radio observations of intense emissions from solar disturbances were made unexpectedly during World War II by military research groups. In England in 1942, it was thought that strong noiselike interference that appeared on radar screens was a jamming signal transmitted by the enemy, but it was very quickly found that sunspot regions were responsible.

In the frequency range of 20 to 200 megacycles per second, this radio energy, when it reaches the earth, has an intensity of about 10^{-21} to 10^{-18} MKS unit (watts per square meter per cycle per second). At times there are violent outbursts, lasting for 20 minutes or so, when the intensity may increase to 10^{-15} unit or even higher. Although these signals originate 93 million miles away, their strength is comparable with that of an average television station 50 miles distant. Solar radio noise has on occasion actually obliterated the pictures on television sets in areas remote from transmitters.

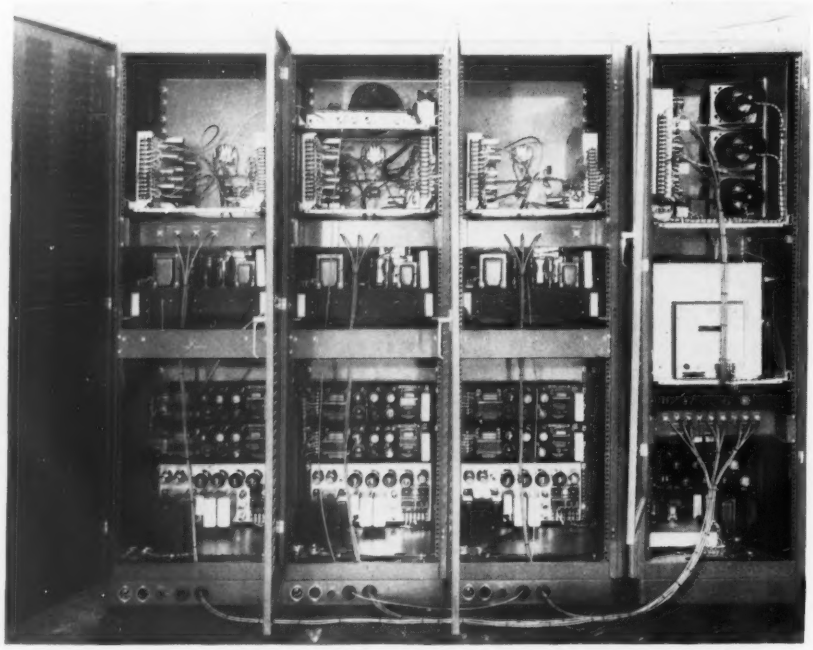
For comparison, the weakest "radio stars" so far detected have intensities at 80 megacycles of the order of 10^{-23} unit, and the background thermal radiation from the sun is some 5×10^{-22} unit.

Since World War II, many observations of solar radio emissions have been made on fixed-frequency receivers, at individual points in the radio spectrum between 20 and 40,000 megacycles. The first spectral or sweep-frequency observations were begun in 1949 by J. P. Wild and L. L. McCready, who had equipment sweeping the band from 70 to 130 megacycles. This work was done at Dapto, about 60 miles south of Sydney, Australia, and was subsequently extended to 40-240 megacycles. It marked a notable advance in solar radio astronomy techniques.

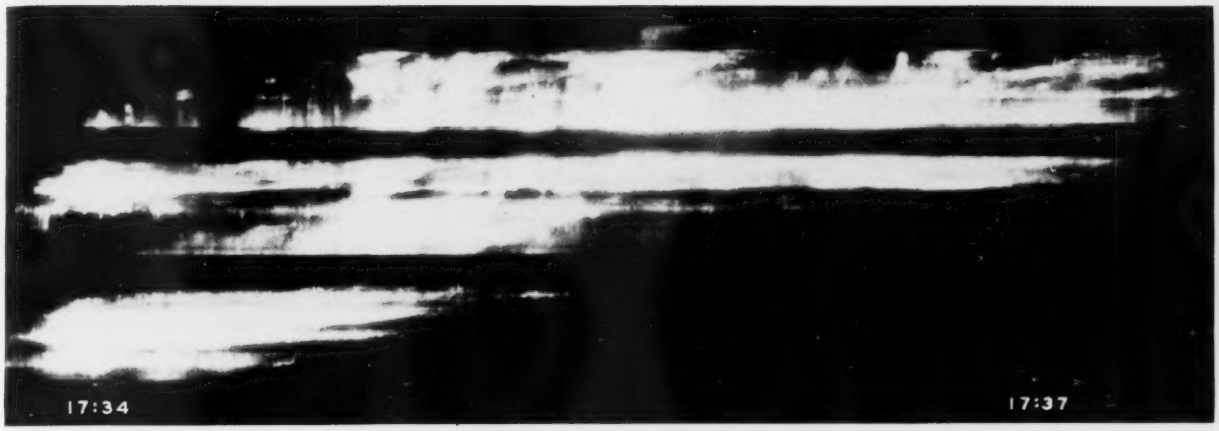
The Harvard Radio Astronomy Station at Ft. Davis, Texas, has been in operation nearly two years. It is essentially concerned with sweep-frequency observations of active areas on the sun, and it forms a radio counterpart to the optical solar observatory at Sacramento Peak, New Mexico, where we had originally intended to set up our equipment.

But the high level of man-made interference from White Sands Proving Ground and Holloman Air Force Base, both directly below Sacramento Peak, made that site unfavorable. Furthermore, the 9,000-foot elevation of Sacramento Peak gives it wide horizons for unwanted television and FM radio signals from distant towns. A careful survey was therefore made of a number of other sites in Texas, Arizona, New Mexico, and Colorado.

The final choice was the floor of a valley in the Davis Mountains of western Texas, within sight of the McDonald Ob-



A view of the racks that contain the sweep-frequency equipment, with the three receivers and the cathode-ray-tube display unit. The C.R.T.'s themselves are at the upper right (see also diagram opposite).



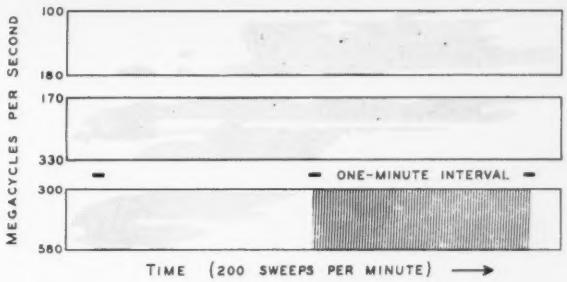
A slow-drift burst of great intensity moving through the whole observing range. It began at 17:34 Universal time, January 7, 1957, and was completely isolated in time from any other activity recorded at Ft. Davis. There were no corresponding optical observations of the sun at that time.

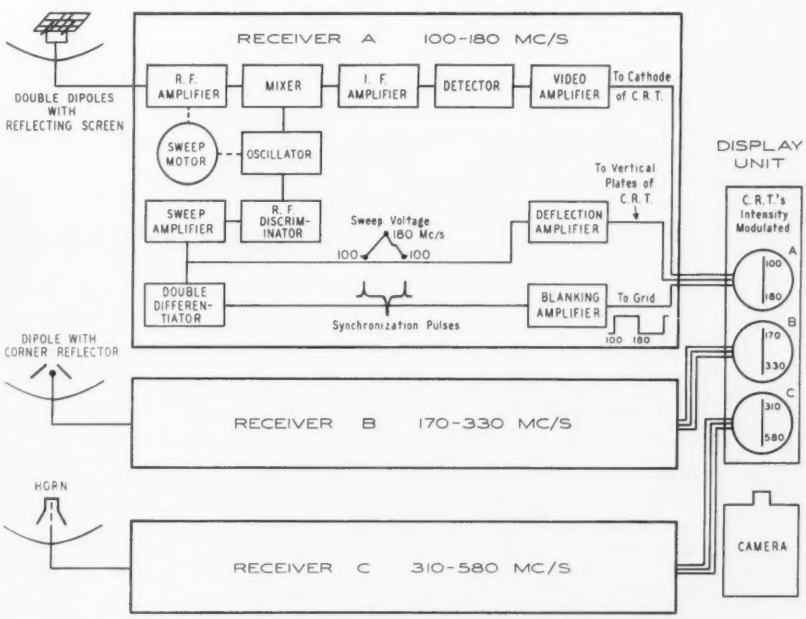
servatory of the University of Texas. At an elevation of about 5,200 feet above sea level, the station is surrounded on nearly all sides by mountains 1,500 feet higher. For frequencies above 35 megacycles, the site is virtually free from radio interference, except for weak television signals from the nearest large towns, over 160 miles away. These unwanted signals are from 100 to 1,000 times weaker at the station site than they are at the top of the Davis Mountains.

The laboratory and antennas are approximately eight miles from the town of Ft. Davis, where the station has an office, a workroom, and two excellently equipped darkrooms for handling film records made by the equipment.

A power line to the station was brought in four miles from the line running up to McDonald Observatory. The main line carries 12 kilovolts, and the station transformer has been placed as far away from the antennas as possible to prevent any possible interference. There is an emergency 10-kilowatt motor generator, which is used occasionally in summer months when the main supply fails during thunderstorms.

The picture above has three parts, identified here to show the relationship of the frequency ranges on the 35-mm. films. The upward sweeps of the cathode-ray-tube spot are sketched for one minute, but are best seen in the noise-storm picture on page 390.



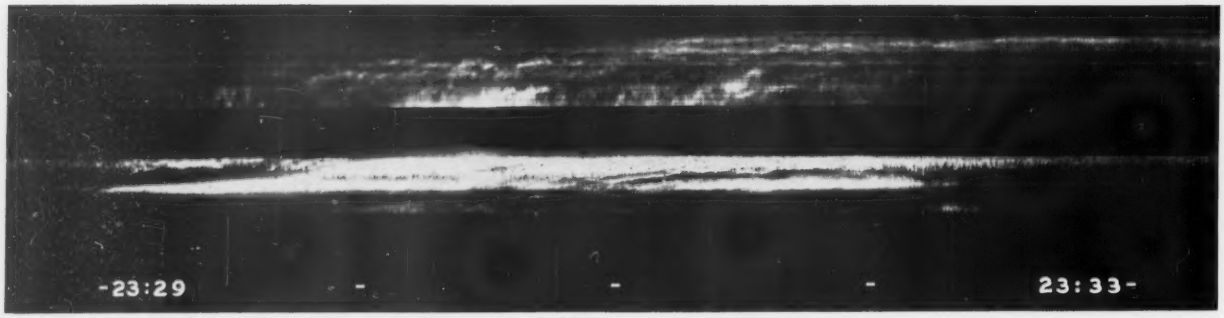


A block diagram of the Ft. Davis solar radio-spectrum analyzer. The circuits of receivers B and C are similar to A. The detector is linear for signals up to about 15 decibels above receiver noise, logarithmic from about 15 to 60 decibels. The 35-mm. camera photographs all three cathode-ray-tube screens together on continuously moving film.

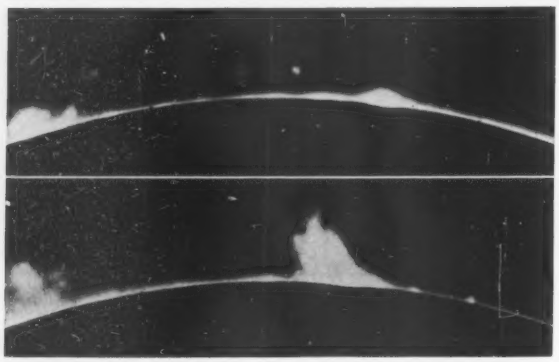
Although the station was not primarily set up for the International Geophysical Year, it is one of the world chain of IGY stations. With the observations made at Ft. Davis and in Australia, the sun's radio emissions are monitored on spectral equipment for approximately 19 hours of the day. We have our own radio transmitter, which permits daily conversations and exchange of observations with the optical observers at Sacramento Peak and the High Altitude Observatory in Colorado. Analysis of the radio records is carried out chiefly by Mrs. Ann Williams.

As with the earlier Australian experiments, the Ft. Davis equipment uses narrow-band tunable receivers that are repeatedly swept across a wide frequency range. But the range is different from the Australian one, the antenna has a somewhat larger collecting area, and the receivers are of higher sensitivity. The receivers sweep concurrently, at the rate of three times per second, and their outputs are displayed on three intensity-modulated cathode-ray tubes. The faces of these tubes are photographed to give records like those illustrating this article.

The three bands are overlapping: 100 to 180 megacycles, 170 to 330, and 300 to 580. The scanning band-width is 0.3 megacycle for the low-frequency range, 0.5 for the middle one, and 1.0 megacycle



A slow-drift burst recorded on May 9, 1957, in the 100-180- and 170-330-megacycle ranges. It was accompanied by a large visual surge prominence at the limb of the sun, as shown by the pictures below. The surge was first observed on the flare-patrol films at 23:28 Universal time, about one minute before the radio burst commenced.



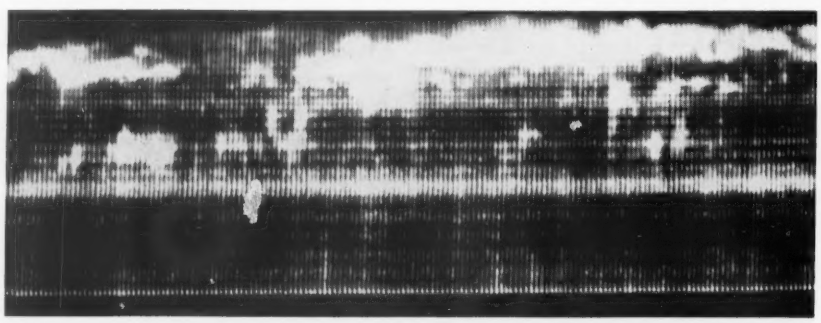
The surge of May 9, 1957, photographed with the 6-inch prominence camera of Sacramento Peak Observatory, at 23:29 UT (upper frame) and 23:40 (maximum of surge). The surge velocity was only 75 kilometers per second, as measured optically.

for the high one, that is, about 1/300 of the range covered in each case. The respective receiver noise figures are six, seven, and eight decibels.

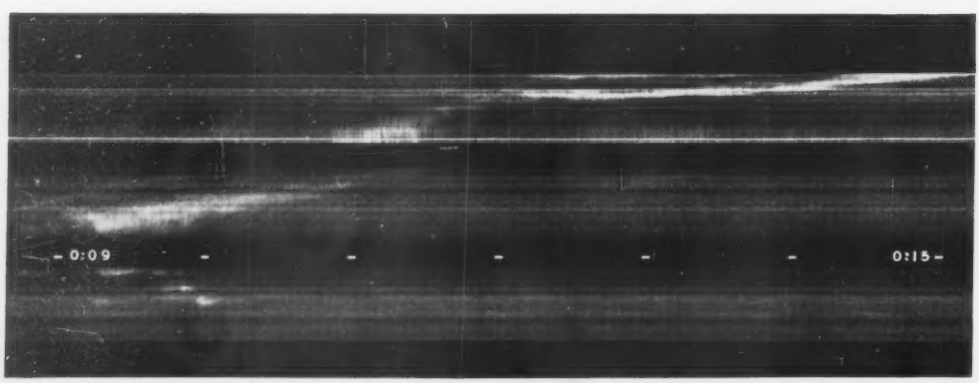
These low noise values are achieved with Western Electric 416-B vacuum tubes in the radio-frequency section of each receiver. The latter consists of two grounded grid amplifier stages, an oscillator, and a crystal mixer. The local oscillator and amplifier circuits are tuned by variable capacitors, which are swept by synchronous motors rotating at three revolutions per second. Because it is not possible to maintain alignment on both the upward and downward sweeps, the receiver output is blanked out for the second half of the rotation, and only the upward sweeps are presented on the display system.

The resolution of the cathode-ray tubes is high — 1,000 lines across each five-inch screen; the spot displacement is proportional to the instantaneous frequency of the receiver, while the brightness is proportional to the receiver output. Three cathode-ray tubes are mounted one above the other, with the lowest frequency range on top. The 35-mm. camera film moves continuously half an inch a minute, recording the intensity of the incoming solar signals as a function of frequency and time. Minute marks on this film are calibrated to an absolute accuracy of one second from WWV time signals. The films are developed to photometric standards.

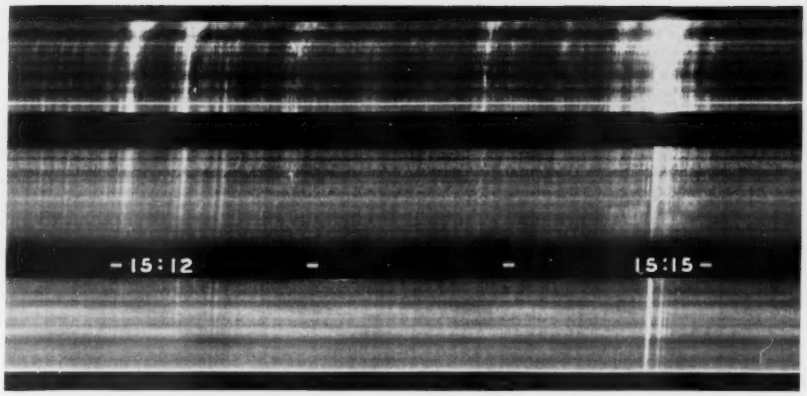
Originally, the limit of the dynamic intensity range of the observations was set by the film emulsion, which cannot handle intensity differences greater than 1,000 to one. Recently, however, the detectors following the amplifiers have been changed from linear detection to linear-logarithmic detection. By compressing the incoming signals in this way, it has been possible to extend the intensity range to 100,000 to one. This is typical of the way in which the inherent flexibility of elec-



A noise storm recorded in the 100-180-megacycle band, on January 19, 1957. This portion of the record covers nearly a minute. The individual cathode-ray sweeps give the vertical fine structure.



On March 2, 1958, this slow-drift burst of weak intensity began at about 0:09 UT. The picture includes nearly the full width of the 35-mm. film, showing the sprocket holes.



Fast-drift bursts recorded on February 4, 1958. This group is typical in intensity, in the way it spreads across the equipment's frequency range, and because it was associated in time with a minor flare on the sun which reached a maximum at 15:12 UT on Sacramento Peak records.

tronic equipment is so frequently used to offset the limitations imposed on a system by its optical, mechanical, or audio sections.

With the receivers sweeping, the existing photographic procedure can detect signals as weak as 5×10^{-22} unit at 100 megacycles, and 10^{-21} unit at 500 megacycles. The equipment is switched on automatically each day at sunrise, and the calibration in frequency and intensity of the day's observations is made after sunset.

The equatorially mounted paraboloidal antenna is 28 feet in diameter, with a focal length of 12 feet. The primary arrays at the focus of the antenna are novel, because they cover such a tremendously wide frequency range. Their design involves correct illumination across the dish, the matching of the feed systems to the dish and to the transmission lines, and the interaction among the three primary arrays themselves. The system represents a compromise of these requirements.

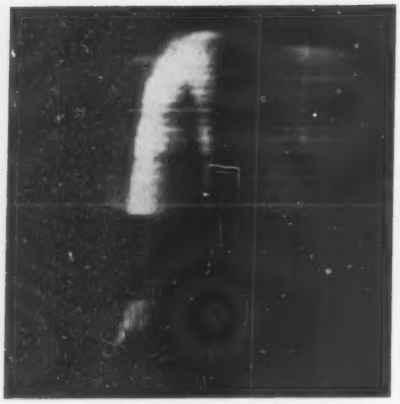
The low-frequency primary array is a double dipole and reflecting screen; the mid-frequency array is a single dipole mounted in a corner reflector; and the high-frequency array is an electromagnetic horn. They are mounted coaxially, and the mid-frequency one is cross-polarized with the other two. The effective collecting area of the antenna is about 42 square meters over the 100-580-megacycle band, corresponding to an efficiency of some 75 per cent.

It has long been known that the intensity of solar radiation, its variability, and other characteristics, change markedly with frequency. The reason is that emission of a given frequency originates at its own characteristic level in the solar atmosphere. For example, radiation at 10,000 megacycles comes from the level about 5,000 kilometers above the visible disk; this is in the chromosphere, where the temperature is of the order of 10,000° absolute. But at 20 megacycles, the energy originates in the corona, some 500,000 to 1,000,000 kilometers above the visible disk, where two-million-degree temperatures prevail. The exact heights corresponding to given frequencies may be greatly increased over an active area on the solar disk, often by a factor of two to five.

On the solar spectral films, the frequency co-ordinate is therefore interpreted in terms of height in the sun's atmosphere. At the present maximum of the solar cycle, the 100-580-megacycle range corresponds roughly to between 500,000 and 50,000 kilometers above the solar disk, and the sweep-frequency receivers monitor the radio emissions from this region.

Sometimes a giant explosion near the solar surface — if at the limb of the sun it is visible as an eruptive or surge prominence — will eject intense, fast-traveling shock waves and jets of fast-moving particles. When these shock waves and streams reach the upper levels of the solar atmosphere, they are detected by the radio signals that they transmit as they pass outward. Some of the particles may even-

The mounting, antenna, and feed system are seen here from the northwest side of the laboratory. Compare this picture with the one on the front cover. The counterweights are oil drums filled with concrete.



Two examples of a "U" burst, which is a form of fast-drift burst. At the left is one that occurred at 18:32 UT on October 21, 1957; note the continuum, in the 100-180-megacycle band, that followed the burst. The event at the right lasted eight seconds on November 29, 1956, at 23:17 UT; the turning frequency was 130 megacycles. In the first 12 months of observation at Ft. Davis, more than 40 bursts of this type were recorded.

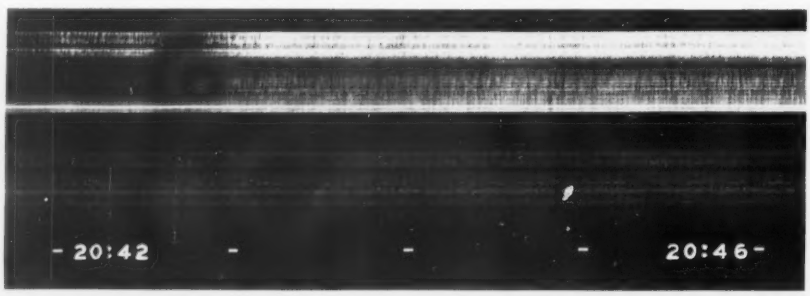
tually reach the earth, where they cause aurorae and magnetic storms; this problem was discussed by Joseph W. Chamberlain in the April and May issues of *Sky and Telescope*.

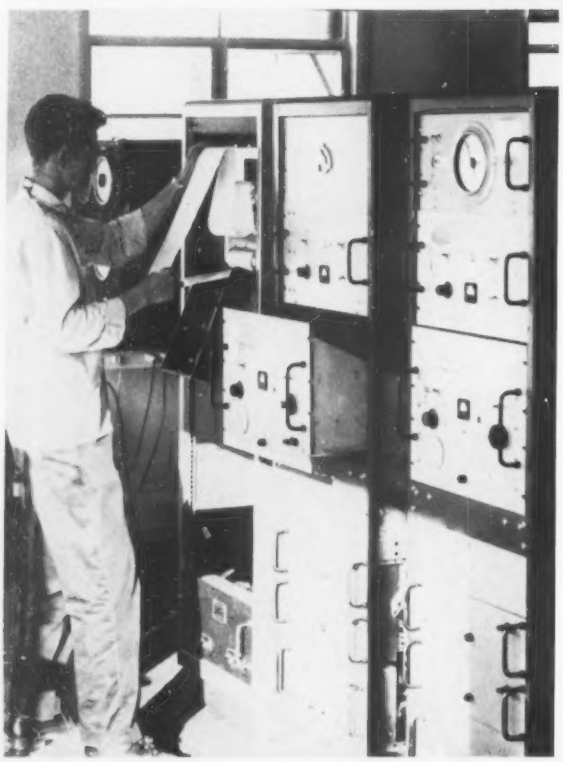
The spectral observations establish the fact that a great majority of solar radio bursts belong to one of four distinct types, reasonably and simply interpreted in terms of different physical processes. This classification has superseded the earlier complex and empirical descriptions of radio bursts from observations taken with single-frequency receivers.

Noise storms. Localized disturbances in the solar corona above active sunspot regions cause noise storms. They consist of long series of short bursts that may continue for hours or days, the individual bursts lasting from a fraction of a second to nearly a minute. Very frequently the bursts have band-widths of only a few megacycles, but at times the band-width may be as much as 30 megacycles.

The noise storms are normally spread over a large frequency range, but are rarely seen at frequencies greater than 250 megacycles. This is one indication that they occur very high in the sun's atmosphere. They are superimposed on a background of slowly varying enhanced radiation; this background may itself sometimes be resolved into hundreds of faint overlapping bursts.

Slow-drift bursts. A narrow band of intense radiation that drifts gradually toward lower frequencies is called a slow-drift burst. The average drift rate is one or two megacycles per second each second downward in frequency, corresponding to motion outward from the sun at 1,000 or 2,000 kilometers per second. This is the velocity of the so-called auroral corpuscular streams, and observations show that in the past year a large number of aurorae and geomagnetic storms have been preceded, about 24 hours earlier, by these slow-drift bursts. Such bursts are relatively rare, recently occurring about three times a month. They are sometimes accompanied by second harmonics in the frequency spectrum.





Above: In this record on March 1, 1958, of the two upper ranges, continuum radiation is seen only in the 100-180-megacycle band. This type of radiation is, however, frequently observed in the other frequency ranges.

Left: A front view of some of the receiver racks in the laboratory building. An assistant, Joe Frank Sproul, is looking at the pen-recorder chart of a 60-megacycle fixed-frequency receiver.

Fast-drift bursts. About 700 fast-drift bursts are recorded each month at the present time. Each lasts about a second, with an extremely rapid drift toward lower frequencies, and they commonly occur in groups of three to 10 within a minute. Such groups are often associated in time and position with minor visual flares. The velocity of the disturbance giving rise to fast bursts is deduced to be of the order of 50,000 kilometers per second. It is suggested that they may be caused either by the outward passage of cosmic rays, or by fast-traveling transverse shock waves.

An interesting variation of fast bursts is a "U" burst. It is believed to originate from the passage of a disturbance traversing a gigantic arc along a closed magnetic field of force above an active area; the disturbance producing the radio energy is thus turned back toward the surface of the sun.

Continuum radiation. A steady en-

hancement of the normal background level of the sun's thermal noise, taking place over a wide band of the spectrum, is called continuum radiation. It is often associated with noise storms, but at times an extremely intense form occurs after great outbursts, or sometimes entirely alone. Continuum radiation may cover a band of more than 300 megacycles for a few seconds to several hours. At present recorded for an average of one hour per month, this continuum radiation may be generated by a large natural synchrotron formed in the solar atmosphere.

Since the Harvard Radio Astronomy Station came into operation at the beginning of September, 1956, observations have been taken daily from sunrise to sunset, and less than five per cent of the possible observing time has been lost. The radio observations continue unimpeded through cloud, fog, snow, rain, or lightning, but when the wind exceeds 50 miles per hour the antenna must be stowed for its own safety.

Thus, continuity of observations is much easier for radio observers than for those using optical equipment. For example, the flare patrol at Sacramento Peak Observatory is limited by weather conditions to about 50 per cent of the possible observing time, and not many other observatories are so fortunate.

It must be emphasized that not all of the interpretations of the solar radio phenomena given in this article are entirely established. For instance, it has not been definitely proved that fast radio bursts are caused by disturbances moving outward through the sun's atmosphere, although this gives the best physical picture so far suggested.

The frequency range of the observations at Ft. Davis will shortly be extended from 100-580 megacycles to 25-580 megacycles, thus including radiations even farther out in the corona. It is expected that the new equipment, at present being developed by A. R. Thompson, will go into operation this coming August.

The work at the station forms part of the research program of Harvard Observatory, and is supported financially by the Air Force Cambridge Research Center.

Astronomers visiting the Ft. Davis station and McDonald Observatory are well acquainted with Indian Lodge in the Davis Mountains State Park.

QUESTIONS... FROM THE S+T MAILBAG

Q. How large will Mars appear at the coming opposition in November?

A. The maximum angular diameter of the disk will be 19.2 seconds of arc, on November 8th when Mars is closest to the earth, eight days before opposition.

Q. Is the fifth satellite of Jupiter visible in amateur telescopes?

A. No. This 13th-magnitude moon is too near its bright primary to be seen except in very large instruments. It was discovered by E. E. Barnard in 1892 with the 36-inch Lick refractor.

Q. Can I perforate the completed mirror of my Newtonian reflector to allow its use in a Cassegrainian telescope?

A. This is not a good idea. Usually, cutting a central hole causes the figure of the mirror to change, because internal strains in the glass are relieved.

Q. If I use 1950 co-ordinates of a star instead of 1958 ones in setting my telescope with the aid of circles, how large an error in pointing can result?

A. At most about seven minutes of arc, much less than the width of the field of a low-power eyepiece.

Q. What part of the sun's total radiation is given out as visible light?

A. About 14 per cent, according to D. H. Menzel in his book, *Our Sun*.

Q. When were the various planets discovered and by whom?

A. Mercury, Venus, Mars, Jupiter, and Saturn have been known since prehistoric times. Uranus was found accidentally by William Herschel on March 13, 1781. The existence of Neptune was predicted by J. C. Adams and U. J. Leverrier, and the planet was first recognized by J. G. Galle on September 23, 1846. Pluto, predicted by P. Lowell and others, was first detected March 18, 1930, by C. Tombaugh on photographs taken in January of that year.

Q. What is the spectrum classification of Gamma Leonis, the bright star in the bend of the Sickle?

A. Gamma Leonis is a double star, and both components are of spectral class *K*0, orange stars cooler than the sun.

Q. What is the velocity of the asteroid Ceres in its orbit?

A. It averages 11.1 miles a second, being about eight-per-cent greater at perihelion (nearest the sun) than at aphelion (farthest from the sun).

Q. How can it be possible that the rings of Saturn are made of frozen material, as proposed by G. P. Kuiper?

Saturn and its rings.

A. At Saturn's distance from the sun, the rate of vaporization of frozen material would be so slow that the small bodies forming the rings would exist indefinitely.

Q. Can I vary the power of my telescope without buying a large number of eyepieces?

A. A good Barlow lens will allow you to use each of your present eyepieces at from about two to three times its rated power. W. E. S.

ASTRONOMICAL SCRAPBOOK

The Brothers Henry

IN the southeastern part of the moon lies a close pair of twin craters bearing a single name, Freres Henry. This unusual joint nomenclature commemorates the French astronomers Paul and Prosper Henry, brothers who collaborated so closely in their scientific work as to appear a single person. They were important pioneers in astronomical photography, but, paradoxically, their success was so great that it crippled astronomy in France for a generation.

The brothers were born at Nancy — Paul in 1848 and Prosper in 1849 — and each at the age of 16 entered the meteorological department of the Paris Observatory. But primarily their interests were astronomical, and at their home they built a 12-inch reflecting telescope and began the construction of star charts.

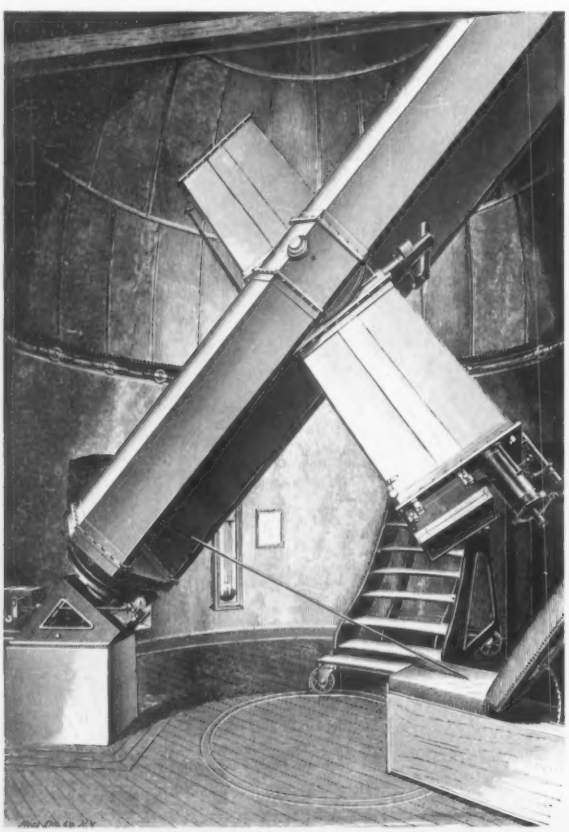
In 1870-71 the Franco-Prussian war altered their lives. German armies swept across France and besieged Paris, where food became so scarce the inhabitants ate animals auctioned off by the zoological garden. Paul and Prosper Henry manned one of the 12 permanent observation posts around the city that maintained a round-the-clock watch on the German batteries and troop movements.

With the return of peace, the brothers were transferred to the observatory's astronomical division, which gave them the use of a large refractor to search for new minor planets. Of these they discovered 14, beginning with 175 Liberatrix on September 11, 1872. With strict impartiality, these discoveries were announced as having been made alternatively by Prosper and by Paul.

A necessary first step in this planet hunting was the laborious construction of maps of faint stars along the ecliptic, by means of old-fashioned visual methods. But when the brothers arrived at the parts of the sky where the ecliptic crosses the Milky Way, the number of stars became so excessive that the task of plotting them one by one seemed beyond human endurance and skill.

Fortunately, at this time photographic dry plates were beginning to come into use, and the Henrys decided to exploit them. At their Montrouge home they erected an optical shop, and constructed a 6-inch objective especially designed for photography. This gave striking results for that time; a 44-minute exposure of the Perseus Double Cluster showed stars as faint as magnitude 12, with perfectly round images.

The importance of these experiments deeply impressed Admiral E. Mouchez, who had become director of Paris Observatory in 1878, as Leverrier's successor, and was famous for his defense of Le Havre during the war of 1870-71. He encouraged the brothers to build a 13½-inch photographic refractor of 11-foot focus, which was completed in May, 1885.



The original astrographic refractor at Paris Observatory, with optics by Prosper and Paul Henry. The box-like tube contains both the photographic telescope and a visual guiding instrument of the same focal length. The northern pier of this double-yoke mounting is outside the picture at the right. From "Washington Observations for 1885," Appendix I, 1889.

The success of this instrument was described by a French scientist 20 years later: "Once celestial photography was realized, the French astronomers divided the universe among themselves: Janssen took the sun, Loewy and Puiseux the moon, and the brothers Henry the stars."

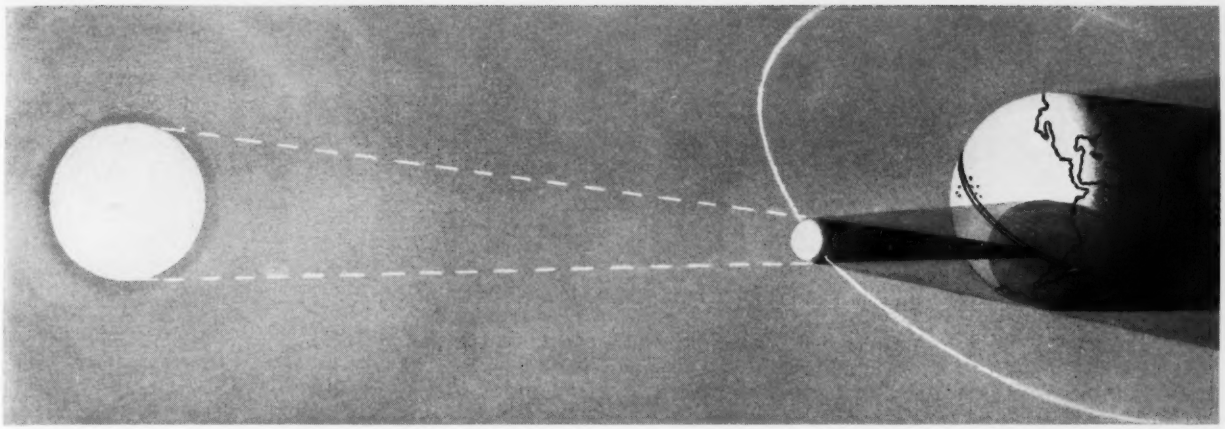
Admiral Mouchez now proposed an extensive international program for the cataloguing and mapping of faint stars by photography. In April, 1887, 57 astronomers from 19 nations met at Paris to draw up plans. The entire sky was apportioned among 18 observatories, each to use a 13½-inch telescope of the Henry design. It was decided to obtain precise positions for all stars brighter than magnitude 11, numbering about one million, and to make charts showing the 25 million stars brighter than magnitude 14.

The 13½-inch astrographic telescope of the Henrys had a field of good definition only about two degrees square, and hence some 20,000 photographs would be needed to cover the sky twice. The Paris congress turned down the plea of the American astronomer E. C. Pickering for the adoption of wide-field doublet lenses, on the ground that these novelties were untried. The assembled astronomers were much more impressed by the excellent performance of the prototype Henry instrument. Besides contributing the adopted design, the Henry brothers made with their own hands about half of the 13½-inch objectives for the program.

Although this huge Carte du Ciel project has never been completed, the portions that were finished have been of very great value to astronomy. The star positions in the catalogues have served astronomers in many ways, and mastering the project's technical problems stimulated many advances in the power and versatility of photographic methods of observation. There is a very interesting account of these matters in H. H. Turner's book, *The Great Star Map*, New York, 1912. We should not overlook the significance of the Carte du Ciel as an early example of large-scale international co-operation in science.

But when the work was started, astronomical photography was primitive. Wide-angle lenses for the observations, and computing machines for the reductions, were unknown when the rigid plans were adopted. Probably the venture was premature; the techniques of later years would have made more manageable the enormous labor of the enterprise. Some idea of the scale of the work is afforded by the experience at Oxford, one of the observatories that completed its share of the catalogue: 20 years and £34,000 were spent in observing, measuring, reducing,

(Continued on page 399)



In this sketch of the October 12, 1958, eclipse of the sun, the dark umbral shadow of the moon, within which the eclipse is total, is crossing the Pacific Ocean eastward and has nearly reached South America. The partial eclipse (penumbral shadow) will be visible at sunrise in eastern Australia, and the closing partial stages may be seen near sunset from portions of South America and Antarctica. The drawing is not to scale.

Observing Plans for October's Eclipse — I

ROBERT J. LOW, *High Altitude Observatory*

THIS FALL'S eclipse of the sun in the South Pacific will be one of the most favorable in recent decades. Totality is long, four minutes or slightly more at the locations from which most observations will be made. The longest duration anywhere along the path is 5.2 minutes, the theoretical maximum being about 7½ minutes. The path width, directly related to the length of totality, is 124 miles, while the maximum possible width is 163 miles.

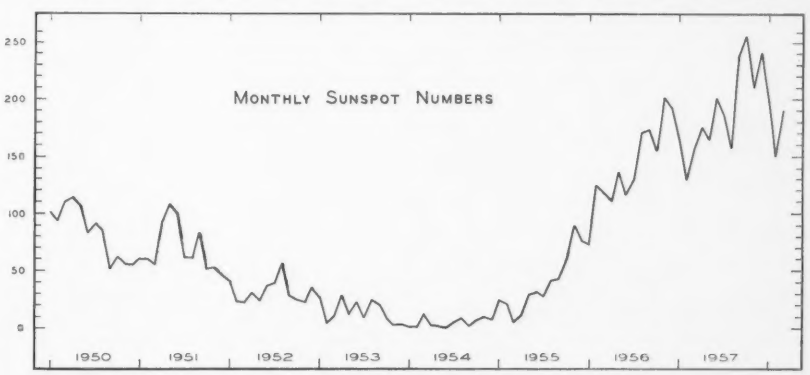
Of far greater importance, however, is the fact that the eclipse will occur near the time of maximum solar activity, and during the International Geophysical Year. The whole IGY program had been planned to coincide with a period of sunspot maximum. How successful the planners were in selecting the time is just becoming apparent. Preliminary reports from Zurich Observatory indicate that we may have witnessed last December the highest relative sunspot numbers ever recorded (and reasonably complete records go back over more than two centuries). Although short-period fluctuations make the picture a little indefinite, it is fairly certain that we shall still have an active sun in October, 1958.

The most thoroughly observed eclipse in history was that of February 25, 1952, which occurred at a time of near-minimum solar activity. The excellent results obtained then should be supplemented by high-quality eclipse measurements of an active sun. These would yield valuable information on the changes of physical conditions that take place over the sunspot cycle, particularly important for investigations of solar-terrestrial relationships and many theoretical problems. It is an exciting thought that the October 12, 1958, eclipse may be one of the most intensively observed in scientific history.

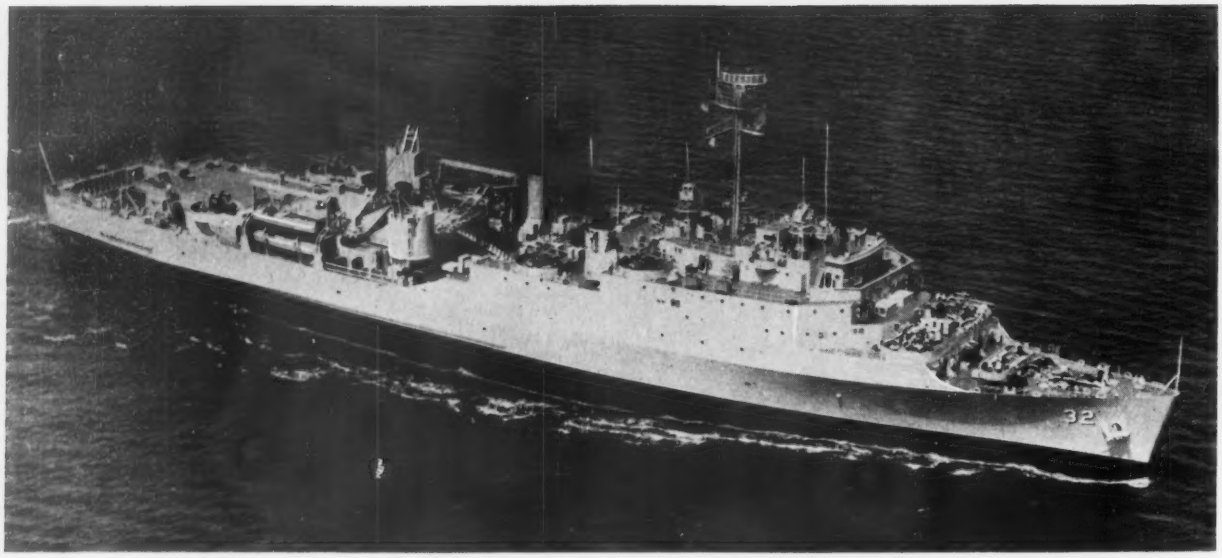
Although it has many favorable aspects, the eclipse has its problems, too. The path of totality begins in the western Pacific near the equator, some hundreds of miles northeast of New Guinea, and stretches east across the Pacific to a point inland from Santiago, Chile. But in passing through the South Seas it misses every one of the large islands. Except for a few small patches of coral that barely rise above the watery expanse, there is no dry land from which observations can be carried out. In South America, the only continental land mass the eclipse path touches, the spectacle will be seen only during the brief moments of sunset.

In *Sky and Telescope* for October, 1956, H. von Klüber told about the circumstances of this eclipse and described the islands in the path of totality. Last October, Frank M. Bateson, who has lived in the South Pacific for many years, wrote in more detail about the individual islands and their native populations. The five American expeditions, whose main experiments will be described later, have selected as their site the Danger Islands, an atoll group located at latitude 10° 55′ south, longitude 165° 50′ west.

The eclipse program is indeed one of the more ambitious and imaginative undertakings of the IGY. Scientific direction of the American effort is being given by the solar technical panel of the U. S. National Committee for the IGY. The U. S. Navy, with Cmdr. O. E. Hearn and Lt. Cmdr. D. P. Wencker handling the



The South Pacific eclipse will occur close to the peak of the highest sunspot maximum in history, as shown by this curve of Zurich monthly mean sunspot numbers (see also the daily sunspot curve on page 410). Solar activity was very low in February, 1952, for the total eclipse observed in Africa and Asia.



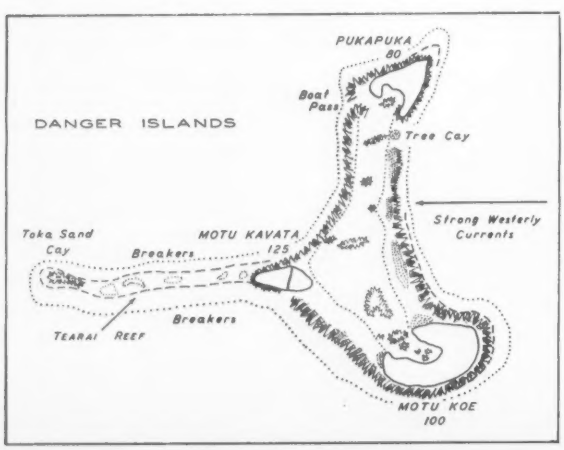
The USS "Spiegel Grove," a sister ship of the LSD that will carry the expeditions. This craft is equipped with almost all the facilities usually found in a fair-sized city. U. S. Navy photograph.

arrangements, is furnishing the USS *Thomaston* for logistic support. This is an LSD (landing ship dock), a large and well-equipped kind of floating drydock, which provides an ideal solution to the transportation problem for the undertaking. There is ample space for equipment and expedition members, and room for the elaborate shipboard launching facilities required for the rockets that are to be fired by the Naval Research Laboratory. There is also a helicopter flight deck, and for this trip a helicopter is to be provided.

The *Thomaston* will sail from San Diego in the middle of August, stop at Hawaii, and arrive at the eclipse site about September 1st. If the Danger Islands were a more typical atoll, the ship would be able to enter the lagoon and ride at anchor there. But the sole entrance, at the northwest near the island of Pukapuka, is only six feet wide at its narrowest point. A team of demolition experts will accompany the expedition, but they will obviously not be able to enlarge the entrance sufficiently to permit the passage of a vessel of such generous proportions as an LSD. And even if it could get inside, it would find the lagoon liberally sprinkled with coral heads just a few feet below the surface.

This means that the *Thomaston* will have to steam back and forth in the open ocean two or three miles from the atoll, because the water there is far too deep and unprotected to anchor. Since the departure from the Danger Islands is not scheduled until about November 1st, there will be many, many miles covered for the purpose of just staying in one place.

We hope to use the southern island, Motu Koe, for our shore station, since it is closest to the central line of the zone of totality. But to get there from the ship through the northwest entrance will be a 10-mile, two-hour trip in Navy small craft. It would be tedious commuting and, in rough weather, quite dangerous. Therefore the helicopter will be used to provide ship-to-shore transportation for men, and perhaps equipment also.



This chart of the Danger Islands, reprinted from the October, 1956, issue, shows Motu Koe, where the American expeditions plan to have their shore station. Heights are in feet, and the scale is about 2½ nautical miles per inch.

Except for a one-week period, when the *Thomaston* will travel to Samoa for refueling, the expedition members will live aboard ship. It will be a sufficiently time-consuming adventure moving the observing equipment ashore, especially if it has to be done by boat. Therefore, no attempt will be made to establish a base camp on the island. The helicopter will save much time on the frequent trips from ship to shore.

The meteorological service of New Zealand, to which the Danger Islands belong, estimates a 60-per-cent probability of clear weather at the time of the eclipse. Fortunately, two of the American experiments, those of the Naval Research Laboratory and the National Bureau of Standards, can be performed in a cloud-filled sky. Even if only these two programs go off as planned, the American effort will be justified.

NRL will fly six rockets at the eclipse: two before, two during, and two after totality. They will be two-stage Nike-Asp solid-fuel missiles, designed to reach 150 miles altitude and to stay aloft five minutes.

The four rockets to be launched during the partial phases will carry instruments to observe the sun's Lyman-alpha radiation and X-rays. Lyman alpha (1216 angstroms) will be measured by means of an ion chamber, such as NRL has used in previous rocket flights at Ft. Churchill, Canada, and San Nicolas Island, California. The X-ray detectors will have mylar and aluminum windows, for observations in two wave-length bands, 44 to 60 angstroms and 8 to 20.

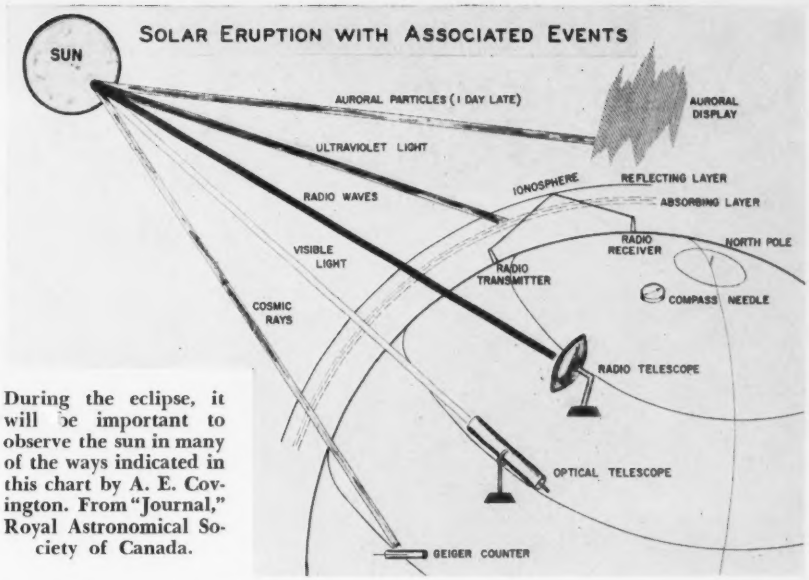
The partial-phase rockets will be seeking information about the role of active regions on the sun in the production of Lyman-alpha radiation and X-rays. For Drs. H. Friedman, T. A. Chubb, and J. C.

Lindsay, the leaders of the NRL expedition, it would be ideal if on October 12th the sun were to exhibit a single highly disturbed region, with no other major activity on the disk. Then their decision would be simple. They would fire one rocket just before the moon covered up the active region and the second one just afterward. The difference between the intensities observed before and after the active region was blocked off would tell them about conditions in the disturbed area itself.

The missiles to be shot during totality will measure the intensity of Lyman-alpha light and X-rays between 44 and 60 angstroms. They will also measure, by means of a proportional counter, the Lyman-alpha light from a sky area three degrees or less in diameter. This will tell us about the positional distribution of Lyman-alpha radiation in the sun's corona, and will help in determining the source of such radiation observed in the night sky.

All these launchings will be to the westward, from shipboard a few miles southwest of the Danger Islands. At eclipse time in mid-morning, the sun will be in the east at an altitude of about 45°. With each rocket headed skyward to the west of the zenith, the flight path will be inclined about 90 degrees to the sun. This gives the optimum position to the instruments for actually observing the sun, since the sensing devices look out of windows on the side of the rocket. Of course the rocket rolls and yaws, but the detectors see quite a broad portion of the sky. These factors together make it fairly certain that the sun will be in the field of view.

For the three-degree Lyman-alpha device, the roll of the rocket provides the scanning. But if the information is to mean anything, it is necessary to know the rocket's orientation for each telemetered intensity measurement. The NRL scientists are confident this very difficult requirement can be met. It is also necessary to know where the rocket is at any moment inside the shadow cone. Its location will determine what parts of the sun are being observed. For example, it will tell whether during totality the detectors are seeing part of the chromosphere.



During the eclipse, it will be important to observe the sun in many of the ways indicated in this chart by A. E. Covington. From "Journal," Royal Astronomical Society of Canada.

All positional and observational information must be sent back to the *Thomaston* by telemetry. The techniques for this are thoroughly developed, but at an eclipse, as everyone knows, there is no second try if things don't work right the first time. Fortunately, there will be two parallel telemetry systems, since during totality two rockets will be aloft simultaneously.

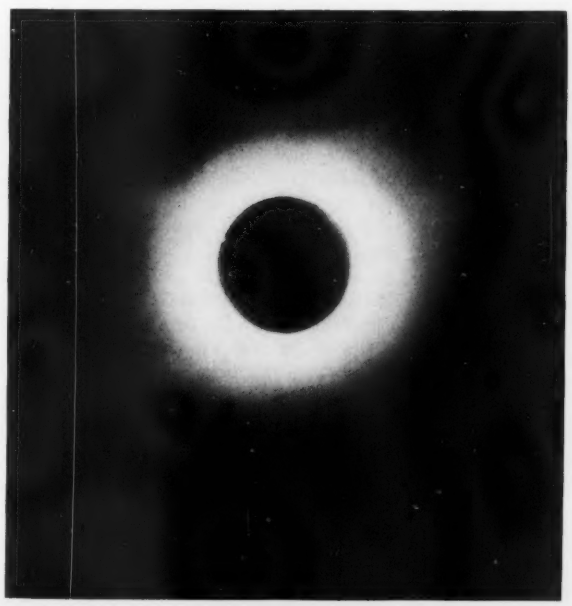
Probably the greatest concern of the NRL group is the use of the second-stage rocket, which is untested in this kind of application. To uncover problems and make necessary modifications, NRL is conducting live tests this June at San Nicolas Island.

The National Bureau of Standards group, working under the direction of T. N. Gautier, has developed a radio experiment whose results should supplement and check the rocket measurements. By the use of a modified vertical-incidence counter, the NBS team will measure changes in the ionization density of the earth's ionosphere at different heights during the course of the eclipse. Since this ionization is primarily produced by the very radiations the NRL rockets will be measuring, the results of the two programs will contribute to each other in a very effective way.

Fortunately, the NBS equipment can be patterned after instruments that have been used successfully for many years. In one experiment, the sounder will transmit vertically 10-kilowatt radio pulses, the frequency of each pulse changing from one megacycle to 15 or higher. These pulses will be reflected from the ionosphere, and the returning signals received at the ground will yield information from which the ionization densities can be calculated. Observations of this sort, mostly made outside of eclipse, have given us most of our current knowledge of ionospheric conditions.

Next month we shall describe the optical experiments of American expeditions and note the plans of other countries.

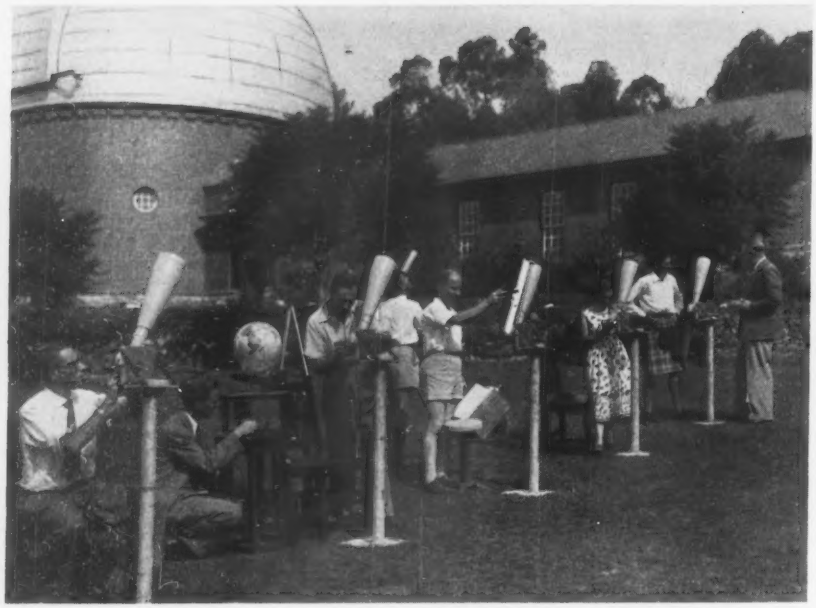
(To be continued)



The total solar eclipse of October 1, 1940, observed from South America and South Africa, was photographed in red light by J. S. Paraskevopoulos, then superintendent of the Boyden Station of Harvard Observatory. This eclipse was the preceding one in the saros cycle that contains the coming October 12th event. The saros interval is 18 years, 10 or 11 days. In this picture, the corona has the rounded appearance typical of a time near sunspot maximum.

ASTRONOMICAL SOCIETY OF THE PACIFIC MEETING

On June 10-12, the Los Angeles campus of the University of California will be the scene for this year's meeting of the Astronomical Society of the Pacific. In addition to sessions for papers, a symposium is scheduled. The society dinner is to take place on Wednesday, June 11th.



The MOONWATCH station at Johannesburg, South Africa, on the grounds of the Union Observatory. Team leader C. N. Williams is tuning the short-wave receiver, while one of the 5-inch telescopes (for observing faint satellites) is being aligned with a clinometer by Mr. van Delen, observatory instrument maker, fourth from right. Observatory director W. S. Finsen is at extreme right.

Some Satellite Studies

RESULTS FROM EXPLORER I

TWO AMERICAN scientists the artificial satellite sent aloft from Cape Canaveral, Florida, on January 31st has proved far more informative than last year's Sputniks. Knowing the properties of Explorer I in detail and having their own instrumentation inside it, they could use this Army moonlet as an experimental tool, instead of merely observing it passively. Preliminary results from the rich harvest of data were reported on May 1st at Washington, D. C., to the National Academy of Sciences and the American Physical Society.

J. W. Siry, Naval Research Laboratory, told of the orbit calculations for Explorer I made at the Vanguard Computing Center in Washington. The orbit computation methods are established by a working group of astronomers: G. M. Clemence, R. Duncombe, J. J. Fleming, and P. Herget, with Dr. Siry as chairman. The center is connected by a high-speed communications system with the network of Minitrack radio-tracking stations. For any satellite launched from Florida, the first radio observations are made by the Minitrack observers at Antigua and Grand Turk in the West Indies. The data are transmitted three times to avoid errors, and are fed into an electronic computer to obtain preliminary orbital elements. Later during the first revolution, Minitrack observations from San Diego, California, become available to correct the calculations.

From subsequent observations, the elements are refined and the changes resulting from air resistance are determined. Dr. Siry estimates that the lifetime of Explorer I (1958α) will be about five to 10 years. At the perigee altitude of 370 kilometers, the air resistance indicated an atmospheric density of about 10^{-14} gram per cubic centimeter. This agrees well with the density (1.5×10^{-14}) reported to the meeting by T. E. Sterne, Smithsonian Astrophysical Observatory, from MOONWATCH and radio observations.

H. De Meyer, an amateur astronomer of Sint-Kruis, Belgium, secured one of the last photographs of Sputnik II before it fell to earth. Here it is passing from Coma Berenices into Virgo, at 19:51 UT on April 13th, about six hours before the last sightings in the West Indies. Mr. De Meyer's observatory was described on page 72 of the December, 1954, issue.

Dr. Sterne used orbit calculations by another Smithsonian astronomer, C. A. Whitney, who had found the period of Explorer I shortening by 0.42 second per day (as of February 1st). During launching, the final stages of Explorer I had been given a spin about the axis of the missile, in order that the body axis would remain parallel to the direction of flight at burnout. But Dr. Whitney finds from the drag data that this parallelism was not achieved; instead, the pencil-shaped satellite was turning end over end. Radio signal-strength measurements at California Institute of Technology's Jet Propulsion Laboratory also indicated that the object was tumbling, with a period of about seven seconds.

Another life-expectancy prediction was presented by L. G. Jacchia, Smithsonian astronomer, who used a simple formula developed by D. C. M. Leslie, in England. It involves only the orbital eccentricity, period, and rate of change of period, and indicates that 1958α should stay aloft a little under five years, until near the end of 1962.

Surprising behavior of the cosmic-ray counters inside Explorers I and III was described to the meeting by J. A. Van Allen of the State University of Iowa. For heights up to about 600 miles, the counts of high-energy particles increased steadily, in a manner compatible with earlier measurements from rockets. But at extreme altitudes, when the satellites were more than 1,000 miles high near the apogees of their orbits, the Geiger tubes sometimes stopped indicating sufficiently strong pulses to be counted, just as if the tubes were being jammed by an intense radiation field.

This interpretation was confirmed in laboratory experiments by Dr. Van Allen and his coworkers, where a similar Geiger counter showed the same failure to respond when subjected to strong irradiation from an X-ray tube. An alternative explanation – that the satellites passed at times through regions very few cosmic rays could reach – appears ruled out, for it would require highly implausible properties of the earth's magnetic field.

For both satellites, it was estimated indirectly that the actual counts at apogee heights would have been as high as 35,000 per second, compared with normal counts of 30 or 40 per second at altitudes of 200 or 300 miles. There is little evidence concerning the nature of this radiation, except that it is not electromagnetic, like light. It might be either protons or electrons, and may have a solar origin.

Dr. Van Allen pointed out that radiation of such intensity would be dangerous to a human being exposed to it for more than a few hours. Unless the potentially dangerous radiation is confined to a relatively thin layer surrounding the earth, future space travelers may require adequate lead shielding.

Among the most important information sought from artificial satellites is the abundance of meteoritic particles in interplanetary space. The National Academy heard the results of two different observing methods used by E. Manring and M. Dubin, of the Geophysics Research Directorate, Air Force Cambridge Research Center.

Gauge detectors developed by Dr. Manring were flown on both Explorer I and III. In this method, 12 tiny wire grids, each one square centimeter in area and containing two layers of very fine wire, are set in an insulated ring mounted flush with the surface of the satellite's midsection. When a meteorite five to 10 microns in diameter (about 1/30,000 inch) or larger strikes one of the grids, the latter's electrical continuity is destroyed. This causes a change in the electric current through the ring, altering the radio signal being transmitted to earth.

Two of the grids of Explorer I were damaged during its ascent, the remaining 10 presenting a total area to space of about 0.001 square meter. Yet, during the first 44 days of orbiting by 1958α, not more than one of the other grids was broken.

The second method, developed by Mr. Dubin and carried only on 1958α, employs a crystal microphone mounted against the skin of the satellite and connected to an amplifier. When the satellite is hit by a micrometeorite of four microns diameter or larger, sufficient acoustical energy is generated to be detected by the microphone. In this system, however, information storage is not provided, and observations can be made only when the satellite is passing over one of the ground stations that can receive its radio signals.

Nevertheless, during the first 12 days of flight of Explorer I, 12 hits were recorded on 65 passages over receiving stations, the total area of meteorite detection on the satellite being 0.0725 square meter.

The preliminary results of the two methods are in fair agreement with each other, when the greater sensitivity to small meteorites and the larger reception area of the microphone method are taken into account. Micrometeorites four microns in diameter are expected to be about three times as numerous in space as those of 10 microns.

A simple experiment with 1958α that appears to solve a serious problem of manned spaceflight was reported by A. R. Hibbs and Mrs. E. P. Buwalda, Jet Propulsion Laboratory, Pasadena, California. Their aim was to hold the interior temperature of the satellite within reasonable limits, despite heating by the sun and the loss of heat by radiation into space.

At Canada's Dominion Observatory, on the morning of March 20, 1958, J. Labreque photographed Sputnik II as it passed through Draco into Hercules (downward). At bottom left edge is Beta Draconis, and the star on the third trail segment is located at 17^h 06^m 22^s, +58° 20′ 0″ (1950). Universal times for the middles of the gaps are: 8:38:09.67, 12.14, 14.61, 17.09, 19.51, 22.07, 24.57, and 8:38:27.04; all of these times are ±0.02 second.

The outside of the vehicle carried parallel strips ¼-inch wide of an aluminum-oxide ceramic known as Rokide. These stripes radiated heat more readily than the uncoated portions of the steel casing, and maintained the internal temperature between +32° and +104° Fahrenheit, well within the limits tolerated by the instrumentation. More elaborate patterns of such striping could be developed to insure even closer temperature control of space vehicles, the California scientists suggested.

Sputnik II Falls to Earth

AFTER completing 2,367 revolutions around the earth, the Soviet artificial satellite launched on November 3rd last year plunged to its destruction in the lower atmosphere on the night of April 13th.

At 8:47 p.m. Eastern standard time, watchers in New England saw this satellite, 1957β, pass southward as a brilliant object, even though it was not in sunlight but in the earth's shadow. It must have become luminous from friction with the air, somewhat as a fireball does. MOONWATCH observers at Milford, Connecticut, at Millbrook, New York, and Bryn Athyn, Pennsylvania, saw the glowing body, the last two places reporting a luminous trail of sparks.

A few minutes later, the Navy ballistic range at Antigua, many ships in the Caribbean, and residents of islands such as Barbados and Trinidad, all observed the striking descent of the moonlet, which was splitting into several fragments. At Barbados, it was said to have a "long trail of fire." Luigi G. Jacchia, of the Smithsonian Astrophysical Observatory, was planning to visit the tropics in May to investigate firsthand the reports of 1957β's final moments.

His preliminary reductions indicate that when the main body was last seen, due east of Trinidad, its height was of the order of 50 to 60 kilometers. Its flight, following closely the path predicted, may have ended near the northern coastline of South America.

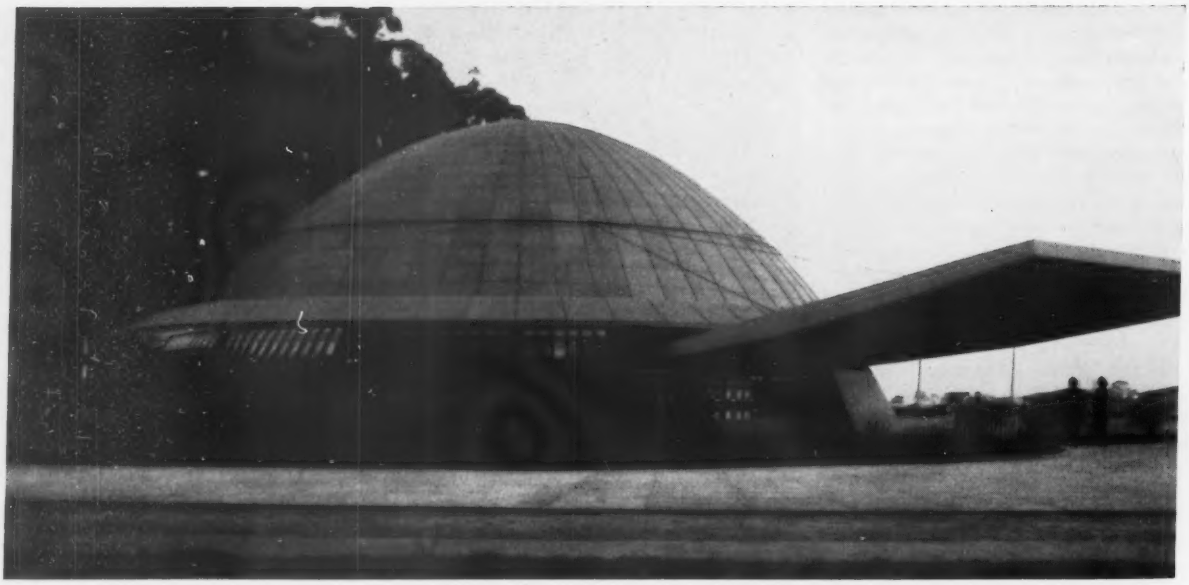
ASTRONOMICAL SCRAPBOOK

(Continued from page 394)

and publishing the places of almost 200,000 stars in its zone of declination, +25° to +31°. At Potsdam, if its original plan of publication had been carried to completion, that observatory's share of the catalogue would have consisted of 387 large volumes filling 45 feet of shelf space and weighing a ton!

It is hardly to be wondered that the co-operating French observatories, Paris, Bordeaux, Toulouse, and Algiers, had their energies committed for decades, while the new science of astrophysics was rising in America, England, and Germany. The whole outlook of French astronomy was confined by the Carte du Ciel project. Perhaps the present flowering of astrophysical research in France would have begun years earlier if the brothers Henry had not made such good lenses!

JOSEPH ASHBROOK



Sao Paulo, now Brazil's largest city, with a metropolitan-area population of 3,300,000, has the first Zeiss projector erected in South America. (Montevideo's planetarium uses a Spitz projector, and was described in the May, 1955, issue.) This striking building is located in Ibirapuera Park, in the heart of a fashionable residential area of Sao Paulo. The photographs on this page were taken by H. Sessler.

Planetarium in Brazil

SINCE its opening 1½ years ago, the Sao Paulo Planetarium has presented several hundred demonstrations. Located in Ibirapuera Park, only 15 minutes from the center of Brazil's largest city, the planetarium building has a seating capacity of 370. Its Zeiss projector was the first in the Southern Hemisphere.

In 1952 the local government appropriated funds for the project, and designs were drawn up by J. C. Figueiredo Ferraz, with construction being supervised by the school building commission.

Because of import restrictions, reinforced concrete, a favorite building material in Brazil, was used for the 65½-foot dome, instead of a projection surface of sheet metal. To correct the resonant properties of the concrete shell, baffles were placed along the supporting walls and sound-absorbing materials in the upholstery of each seat. The resulting acoustics are so satisfactory that a public-address system is not needed.

As there has been a shortage of experienced lecturers, no regular schedule is followed for planetarium showings. Prof. Aristoteles Orsini, a department head at Sao Paulo University and president of the local astronomy club, has been in charge of the programs.

The Sao Paulo Amateur Astronomical Association uses corridors around the planetarium chamber for displays of amateur telescopes, mirror making, star charts, and other exhibits. The group also distributes free literature. A second local club is the Sociedade Brasileira de Selenografia, devoted to lunar observing.

O. DIAS DE ALMEIDA
Rua Gen. Telles 369
Sao Paulo, Brazil

During a demonstration of the Sao Paulo Planetarium, the Zeiss projector is seen against a representation of the city's skyline.

CORRECTIONS

Dr. G. de Vaucouleurs, Lowell Observatory, calls attention to an editorial misidentification in the caption of the picture showing three galaxies, at the top of page 231 of the March, 1958, issue. The upper left object is NGC 3995 (not 3994), and the lower left is NGC 3994 (not 3995).

On page 336 of the May issue, there is a typographical error, as the date of the Michelson-Morley experiment was 1887 and not 1881.

The Densities of Gaseous Nebulae

OTTO STRUVE
Leuschner Observatory
University of California

Among the most beautiful nebulae in the sky is this one, surrounding the variable star Eta Carinae. Harvard Observatory photograph.

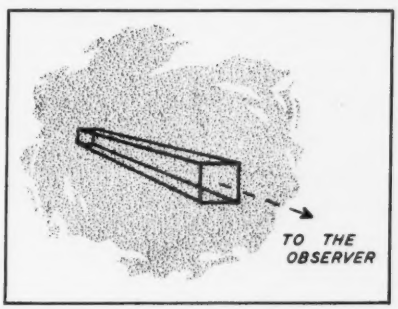
MOST amateur astronomers have at some time turned their telescopes to a point about two degrees southeast of the star Beta Ursae Majoris, to view the Owl nebula, Messier 97. In small telescopes, it has a faint planetlike disk, but very large apertures or good photographs show the curious structure that led Lord Rosse to give this nebula its special name.

The gaseous nebulae, of which M97 is an example, have been known since 1619, when the Swiss astronomer Cysatus accidentally happened upon the Orion nebula while observing a comet with the newly invented telescope. The true nature of the nebulae was long in doubt; William Herschel even suggested that they were all remote and unresolved star clusters.

But in 1864 a famous English astronomer and spectroscopist, William Huggins, noticed that the spectrum of a small nebula in Draco consisted of bright lines. Such emission lines could only originate in a tenuous gas, and we know now that the chief constituent of the nebulae is hydrogen. Perhaps the most striking physical property of a gaseous nebula is its very low density, a nearly perfect vacuum by terrestrial standards. The nebulae have been described as celestial laboratories where the properties of radiation and matter can be studied under extreme conditions, including light paths many parsecs long in highly rarefied gases.

In this article, we shall consider a new method of determining the density of a gaseous nebula, based largely on the theoretical ideas of M. J. Seaton in England, and applied observationally in America by L. H. Aller and especially D. E. Osterbrock. But before proceeding with their work, we can gain some insight into nebular densities by reviewing a procedure described in 1933 by the Soviet astronomer V. A. Ambarzumian, in a fundamental paper that appeared in Vol. 6 of the *Zeitschrift für Astrophysik*.

For simplicity, imagine a nebula that consists of hydrogen gas only. When excited to shine, it will emit spectral lines of the Balmer series, Hα, Hβ, Hγ, and so forth. Suppose that we can measure the total energy that is emitted in a certain emission line — say Hβ, the green line at wave length 4861 angstroms — from one square centimeter of the surface of the nebula in one second of time. The light from this area comes from hydrogen atoms located inside a column whose length, l, is the thickness of the nebula and whose cross section is one square centimeter. If each cubic centimeter of nebular material contains n hydrogen atoms, their total number inside the column is nl.



Illustrating the example in the text, of a nebular column of gas having a cross section of one square centimeter.

But not all of these nl atoms are emitting Hβ light. In the first place, many of them are ionized into free protons (hydrogen nuclei) and free electrons, and so do not emit radiation of discrete wave lengths. In a typical gaseous nebula, there are about 1,000 protons for each neutral (un-ionized) hydrogen atom; hence only $10^{-3}nl$ atoms are available to produce spectral lines.

Secondly, the Hβ line is produced by hydrogen atoms changing from the fourth to the second energy level or state, and at any given moment only a very small fraction, about 10^{-13} of the hydrogen atoms, are in the fourth energy state. Hence, the number of hydrogen atoms inside the column that actually can produce Hβ is approximately $10^{-13} \times 10^{-3}nl$, or $10^{-16}nl$.

The total energy emitted at this wave length by one square centimeter of the surface is the product of three quantities: the number of atoms available for the production of Hβ ($10^{-16}nl$), the number of times per second each of these makes the necessary transition from the fourth to the second energy level (10^7 times), and the amount of energy that is emitted by a single transition (calculated from atomic theory as about 4×10^{-12} erg). The

result is $4 \times 10^{-21} nl$ ergs, which we shall designate by E.

From this we have a formula for the density of the hydrogen,

$$n = E/(4 \times 10^{-21} l).$$

Thus Ambarzumian's problem was reduced to the observational one of measuring E, the energy in the Hβ spectral line.

A monochromatic image of a nebula producing only an emission-line spectrum can be observed either through a suitable filter or by means of a spectrograph with a very wide slit. On the Hβ image we can then measure the total brightness, in some arbitrary units, of a small area, say a square second of arc.

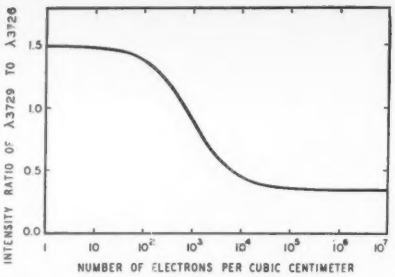
In principle we next photograph the sun through a filter transmitting only a one-angstrom stretch of the continuous spectrum near Hβ, and measure the solar brightness in the same arbitrary units for an area of one square second. The ratio of the two measured brightnesses is independent of the arbitrary unit. If this ratio is x, then one square centimeter of the sun's surface emits x times as much light within the one-angstrom interval as does one square centimeter of the nebula's surface in Hβ.

The last link in the calibration is provided by Planck's law, stating the amount of radiant energy of a luminous surface as a function of wave length and the temperature. Within a one-angstrom band in the vicinity of the Hβ line of the solar spectrum, each square centimeter of the 6,000° solar photosphere is emitting about 10^7 ergs per second.

So, essentially, our observational problem would be solved by comparing the blackening of photographic film produced by the sun and the nebula, provided both pictures had the same exposure time. In reality, however, the sun is much too bright to permit such a direct comparison.

Hence, Ambarzumian introduced an intermediate standard of brightness: a comparison star of known apparent magnitude and precisely the same spectral type and intrinsic luminosity as the sun. Such a star would also emit 10^7 ergs per second per unit area in a one-angstrom band near Hβ. At the same time, the star and nebula can be similar enough in brightness to be observed with the same instrument, in Ambarzumian's case the 40-inch reflecting telescope of Simeis Observatory.

He measured the ratio of i_n, the brightness of a one-square-second area of the monochromatic image of the nebula, to i_s, the brightness of the *entire* star within a one-angstrom interval. The exposure times for the nebula and the comparison star were the same.



D. E. Osterbrock has calculated this curve, which shows how the oxygen 3729/3726 intensity ratio drops from 1.5 to below 0.5 as the number of electrons increases from one to 10,000,000 per cubic centimeter. This revises an earlier curve published in the September, 1955, "Astrophysical Journal."

Ambarzumian had to apply two corrections to make the nebula-star comparison give the same result as a nebula-sun comparison would, one for the difference in distance from us of the sun and the star, the other for radiation from the entire sun instead of just one square centimeter.

Consider the first correction for Ambarzumian's observations of the planetary nebula NGC 6572 in Ophiuchus, for which he used the comparison star 15 Sagittae. The star's apparent magnitude is +6, that of the sun −27, making a difference of 33 magnitudes. Since a one-magnitude difference corresponds to a ratio of 2.512 in light intensity, the star is about $(2.512)^{33}$ or 1.6×10^{13} times *fainter* than the sun, making a correction factor of $1/(1.6 \times 10^{13})$.

The area of the sun's disk is 3×10^6 square seconds of arc, approximately, and multiplication by this number performs the second correction. Applying both factors, the true value of the ratio of surface intensities, nebula to sun, becomes $2 \times 10^{-7} i_n/i_s$.

Ambarzumian in his paper did not list the measured ratios i_n/i_s, but we infer that for a typical nebula it was about 0.25. Hence, the ratio we are seeking is about 0.5×10^{-7}. Since one square centimeter of solar surface emits 10^7 ergs per second in a one-angstrom interval near Hβ, the corresponding area of the nebula's surface emits

$$E = 0.5 \times 10^{-7} \times 10^7 = 0.5$$

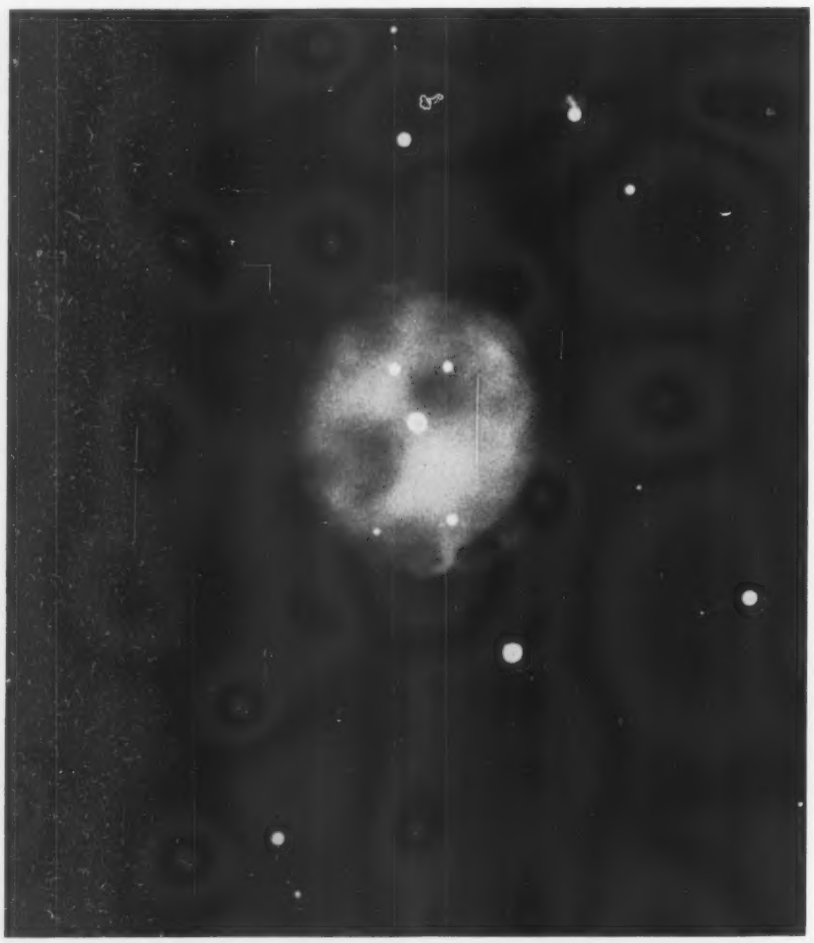
erg per second of Hβ light.

As we have seen, the total number of atoms contributing to the observed emission is given by the first of the formulae. Usually the thickness l is known only approximately. If it is about one light-year or 10^{18} centimeters, the density of the nebula is

$$n = 0.5/(4 \times 10^{-21} \times 10^{18}),$$

or approximately 100 hydrogen atoms per cubic centimeter.

This method of Ambarzumian has been used, with many important improvements, by Aller and D. H. Menzel. In

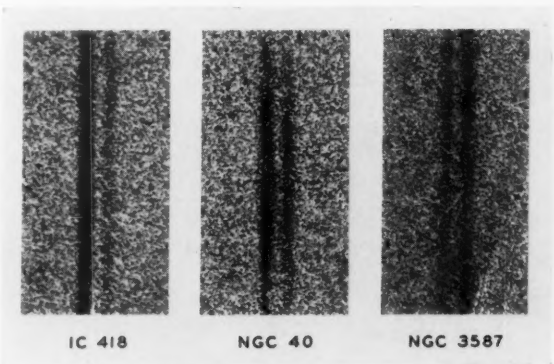


NGC 3587, the Owl nebula in Ursa Major. Mount Wilson Observatory photo.

the work by W. Liller, the surface brightnesses of the nebulae were measured photoelectrically (see *Sky and Telescope,* August, 1957, page 472). But the method is not very reliable, because many of the quantities involved are not accurately known, for example, the ionization and excitation of the nebular gas, and the thickness of the nebula. Also, in some cases the nebula absorbs an appreciable fraction of its own radiations, an effect we have ignored.

The new method by Seaton, Osterbrock, and others eliminates all of these difficulties. It gives the density of a nebula directly from a very simple observation, and it constitutes a real breakthrough in astrophysics.

The observation is a measurement of the intensity ratio of the two components of an emission line from ionized oxygen, at 3726 and 3729 angstroms in the ultraviolet. On low-dispersion spectrograms these components coalesce and their intensity ratio cannot be ascertained, but even moderate-power instruments resolve them. It turns out that the 3729 line is about 1.5 times as intense as 3726 in some nebulae, about 1.0 times in others, and in still others about 0.5.



The oxygen doublet, having 3729 on the right in each case, is compared on three spectrograms of planetary nebulae. The Cassegrainian spectrograph of the 60-inch reflector was used, dispersion 55 angstroms per millimeter. Mount Wilson and Palomar Observatories photograph.

At first sight such differences are rather surprising, because these emission lines originate in transitions to the ground level from two very close excited states of oxygen atoms that have lost one electron. Both transitions are termed *forbidden,* meaning that they are not expected to be observed in laboratory experiments. If an oxygen atom gets into one of the two excited states, it must remain there, undisturbed, for minutes or hours before it emits radiation (not for 10^{-7} second as with the fourth state of hydrogen). In ordinary laboratory experiments an atom never can remain undisturbed so long; it collides with another particle or the wall of the container, and is knocked into some other state before it can emit the forbidden line.

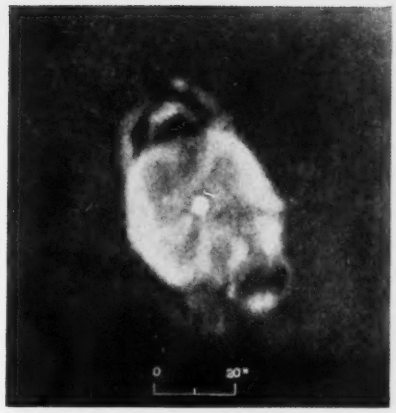
In a nebula, on the other hand, the density is so low that many OII atoms in an excited state can travel without collision until they can radiate either 3726 or 3729 light.

According to I. S. Bowen's interpretation of many years ago, most OII atoms get into one of these two excited states as the result of collisions with free electrons. Seaton has computed that three-fifths of such atoms are lifted by collisions into the *lower* excited state and become capable of emitting 3729 radiation; two-fifths of them are lifted into the *upper* excited state and become able to emit 3726. If the atoms are not disturbed by later collisions while they are in the excited states, each will ultimately resume its ground state and emit one of these wave lengths. To insure that a collision will not occur, the density of free electrons must be very low, and this is the key to our interpretation of the intensity ratios observed in different nebulae.

At extremely low electron densities, 1.5 times as many atoms produce the 3729 line as produce 3726. In this case the observed ratio 3729/3726 should be 1.5.

At considerably higher electron densities, however, many atoms are knocked out of the excited states by collisions that occur before the radiation can take place. The average populations of the excited levels automatically adjust in accordance with known rules, and the intensity ratio of the two lines is reversed, 3729 being less than 0.5 as strong as 3726. Densities intermediate between these extremes give intensity ratios ranging from 1.5 to under 0.5, as observed in the nebulae.

We have already noted that hydrogen is the principal constituent of the gaseous nebulae and almost all of it is ionized. Hence, for practically every electron there is a proton, and the proton density is numerically equal to the electron density derived from the observed intensity ratio of the oxygen lines.

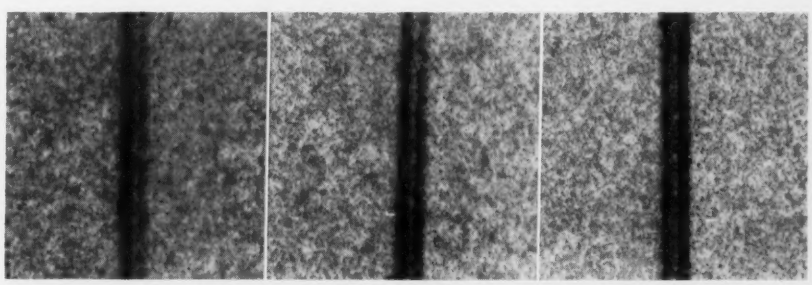


A drawing by H. D. Curtis of the planetary nebula NGC 40, in Cepheus. From "Publications" of Lick Observatory, Vol. XIII, 1918.

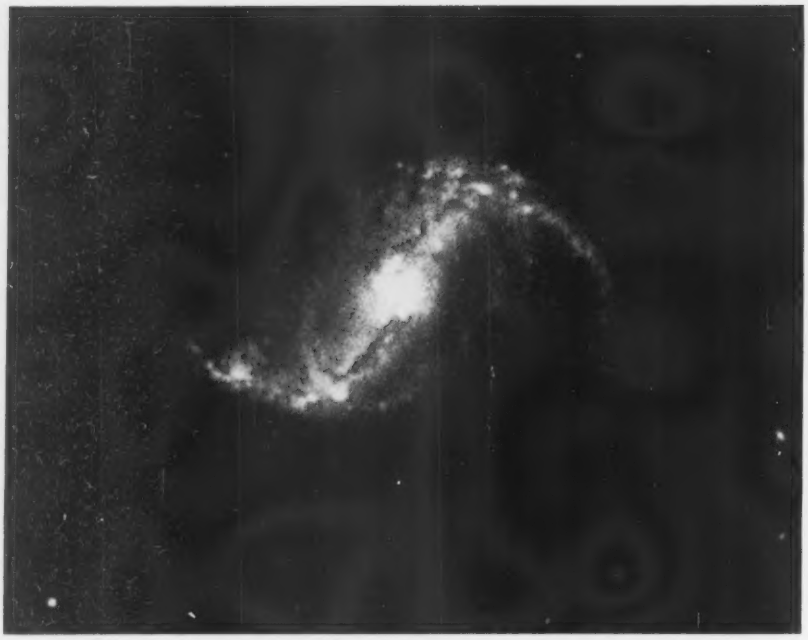
Observationally, we can infer that the planetary nebula IC 418, in which 3729 is much weaker than 3726, is much denser than NGC 3587, where the 3729 line is the stronger of the two. To provide a basis for quantitative values, Seaton has made a series of elaborate computations which were used in the diagram on page 402. We can infer at once from this curve that IC 418 contains at least 10,000 atoms per cubic centimeter, while the corresponding number for NGC 3587 must be about 100.

Some particularly interesting results are given by different parts of the Orion nebula, based on the work of Osterbrock. The new method gives a high density, about 20,000 atoms per cubic centimeter, for one of the brightest central parts. On the other hand, a spectrum taken of a fainter part, about one-fourth of a degree from the Trapezium, indicates a density of only 300.

This new way to determine the densities of the gaseous nebulae will have far-reaching importance, because these nebulae are very closely connected with many problems of the astronomy of stars and galaxies.



At many points in the Orion nebula, NGC 1976, D. E. Osterbrock has photographed the oxygen doublet, three cases being shown here. They are distant from the Trapezium by 0.7 minute of arc (left), 2.6 minutes (center), and 16.3 minutes (right), the first having by far the greatest electron density. Mount Wilson and Palomar Observatories photograph.



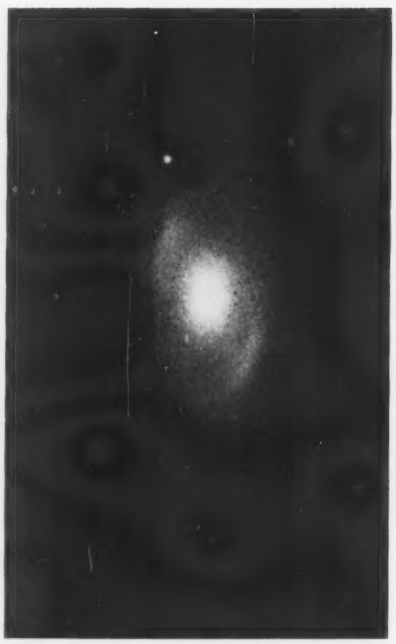
The galaxy NGC 986 is a barred-spiral system, composed of millions of stars with great clouds of gas and dust. This enlargement is from a one-hour exposure on December 18, 1952, and has a scale of about 2.4 seconds of arc per millimeter. A blue-sensitive emulsion was used without a filter, so the arms appear brighter in comparison to the central regions than would be the case with a red-light photograph.

Among Southern Galaxies—V

WITHIN the constellation Fornax are the three southern galaxies featured this month — NGC 986, NGC 1079, and NGC 1097. Amateur observers will find the first and third plotted in Norton's *Star Atlas*, where NGC 1097 is labeled 48^s, from its designation in William Herschel's catalogue.

At the top of this page is NGC 986, a regular barred spiral very similar to but a little earlier in classification than NGC 613, which was discussed and pictured in last month's issue on pages 334-335. NGC 986 is at right ascension $2^h\ 31^m.6$, declination $-39°\ 15'$ (1950 co-ordinates), and is of photographic magnitude 11.4. Its outlying portions cover an area about 3.7 by 2.9 minutes of arc. Its spiral arms become very faint, but extend to form almost complete loops, which do not show in the reproduction.

G. de Vaucouleurs, Lowell Observatory, points out that the circular outline of these loops indicates the elliptical shape of the inner ring of the system is real and not due to tilt. He classifies NGC 986 as type SB(rs)b, according to his system explained on page 582 of the October, 1957, issue. He finds a few emission knots in the picture, but no individual stars are resolved, indicating a distance greater than 30 million light-years. The spectral type and red shift of this galaxy are still undetermined.



Faintest of the three galaxies on these pages is NGC 1079. This one-hour blue-light exposure with the 74-inch reflector was made on September 5, 1953. Here the scale is 2.6 seconds per millimeter.

At first sight NGC 1079, pictured below, is a small galaxy of elliptical shape, with two opposite bright sectors on the rim of a halo surrounding the nucleus. Its extreme dimensions are 1.5 by 0.8 minutes of arc, confirming the values in the Shapley-Ames catalogue, where its magnitude is given as 12.6. On the negative, however, there is a very faint oval arm structure extending five minutes from east to west and three minutes from north to south. NGC 1079 is an SBa-type spiral, at right ascension $2^h\ 41^m.6$, declination $-29°\ 13'$.

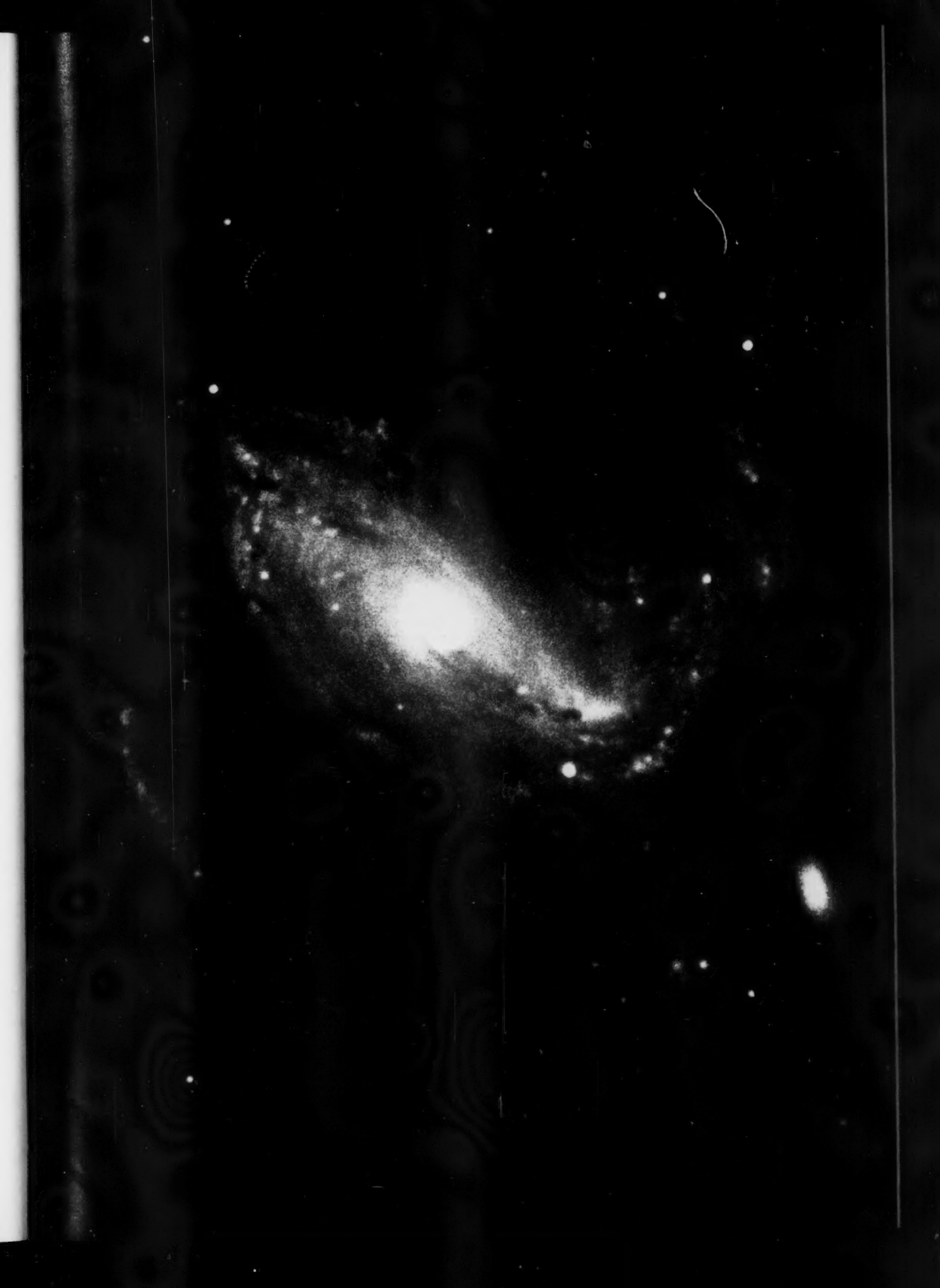
Pictured opposite is a superb barred spiral, NGC 1097, of intermediate type SB(s)b in the de Vaucouleurs classification. Short exposures of its very bright nucleus disclose an innermost spiral pattern of bright and dark matter, and it has dark lanes of obscuring matter running parallel to the bar, as in NGC 613 and NGC 986. The outer arms are partially resolved by the 74-inch reflector into stars of apparent magnitude 20 and fainter, together with some brighter patches of emission nebulosity. There are very extensive faint outer arms.

Of magnitude 10.5 photographically, NGC 1097 has extreme dimensions of about 10 by seven minutes of arc. It is at right ascension $2^h\ 44^m.3$, declination $-30°\ 29'$, far enough north for observers in most of the United States. Milton L. Humason gives its nucleus a spectral type of *F*8, and measures a velocity of recession somewhat more than 1,200 kilometers per second.

Note the increasingly loose texture of the spiral arms in the sequence NGC 1079, 1097, and 986, corresponding to the Hubble types SBa, SBb, and SBc, respectively.

FACING PICTURE: The barred-spiral galaxy NGC 1097, photographed with the 74-inch telescope of Radcliffe Observatory, at Pretoria, South Africa. This 50-minute exposure, on November 16, 1952, was made in blue light, on an Eastman 103a-O plate without a filter. The reproduction scale is about 2.0 seconds of arc per millimeter.

These are some more photographs in a monthly series of southern-galaxy pictures from the new atlas compiled by the Royal Cape Observatory, as described on page 519 of the September, 1957, issue of "Sky and Telescope." The series began in the February, 1958, issue. Several hundred exposures were made by Cape staff members with the 74-inch reflector, in order to obtain the two dozen high-quality negatives selected for the first installment of the atlas. The pictures are being published with the permission of Her Majesty's Astronomer at the Cape, R. H. Stoy. Each atlas print is accompanied by descriptive material written by David S. Evans, astronomer on the Cape Observatory staff.



NEWS NOTES

CLUSTERS OF GALAXIES AND INTERGALACTIC OBSCURATION

Statistical studies of clusters of galaxies yield more important information about the large-scale structure of the universe than do statistics of galaxies as individuals, according to F. Zwicky, Mount Wilson and Palomar Observatories. In the December, 1957, *Publications* of the Astronomical Society of the Pacific, he summarizes extensive counts of galaxies and clusters from photographs with the Palomar 48- and 18-inch Schmidt telescopes and the 200-inch Hale reflector.

"The apparent distribution of galaxies," writes Dr. Zwicky, "can be understood if clustering of galaxies is admitted to be a universal phenomenon and if the effects of properly distributed intergalactic dust are taken into account."

He notes that distant clusters of galaxies are abnormally rare in the fields covered by very large and rich nearby clusters. This would indicate that intergalactic dust is concentrated inside large clusters. In addition, the more powerful 200-inch telescope shows very few clusters that are not detectable with the 48-inch Schmidt. Dr. Zwicky therefore believes that, for regions of space beyond the reach of the 48-inch telescope, intergalactic dust markedly reduces the total number of clusters recognizable with the 200-inch.

Another finding of the Mount Wilson and Palomar astronomer is that double and multiple clusters of galaxies do not occur, and that there are no clusters of clusters.

This conclusion is controversial. George O. Abell, now of the University of California at Los Angeles, has studied the distribution of 1,682 rich clusters of galaxies on 48-inch Schmidt photographs for the National Geographic Society-Palomar Observatory Sky Survey. He believes that his data indicate the existence of second-order clusters of galaxies. Dr. Abell's results have been published as *Astrophysical Journal Supplement* No. 31.

R. F. SANFORD DIES

A famous observer of stellar spectra, Roscoe F. Sanford, passed away on April 4th at Pasadena, California. He was 74 years of age. Dr. Sanford retired from the staff of Mount Wilson and Palomar Observatories in 1949, after 31 years of service.

Upon graduation from the University of Minnesota, he worked from 1908-11 at San Luis, Argentina, in a Carnegie Institution of Washington project to determine accurate positions of Southern Hemisphere stars. During the next four years, he was a member of the Lick Observatory expedition to Santiago, Chile, where he made spectroscopic measurements of stellar velocities.

After obtaining his doctorate from the University of California, Dr. Sanford joined the Mount Wilson staff in 1918, where he continued his spectroscopic investigations with the 60- and 100-inch telescopes. He pioneered the application of high-dispersion techniques to numerous variable and double stars.

Dr. Sanford earned world-wide recognition for his spectrum photographs of cool red carbon stars, and his observations supplied new information concerning the constitution and motions of these objects.

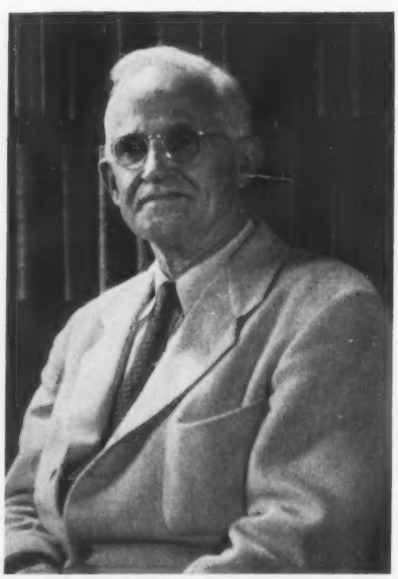
RADIO-NOISE CONFERENCE

More than 200 astronomers, geophysicists, and communications engineers attended a conference on the radio-noise spectrum, at Cambridge, Massachusetts, on April 22nd. Harvard Observatory sponsored the meeting, which had papers ranging from the control of man-made radio interference to 21-cm. radiation from neutral hydrogen in interstellar space.

Some highlights of the morning session were A. M. Peterson's report on radio echoes from aurorae, G. S. Hawkins' finding that meteors do not emit appreciable radio noise, and papers by R. Gallet and R. A. Helliwell on noise of very low frequency from the upper ionosphere.

In the afternoon, A. E. Lilley, Yale University, received the Bart J. Bok prize in astronomy. Papers on solar radio noise were presented by A. Maxwell, T. Gold and D. H. Menzel, while radiation of planetary origin was discussed by B. F. Burke.

For the use of radio engineers, Dr. Menzel presented planisphere-type maps of cosmic radio noise, covering the entire sky and including the strongest discrete sources. With such a map, an engineer can calculate for his antenna the background level of noise interference for any time of day and year. The maps were prepared under contract with the U. S. Army Signal Corps, which also supported the conference.



Roscoe F. Sanford (1883-1958).

NATIONAL ACADEMY OF SCIENCES AWARDS FOR ASTRONOMY

On April 28th the National Academy of Sciences gave seven medals in recognition of outstanding research achievements. Three of the citations were for astronomical work.

Horace W. Babcock, Mount Wilson and Palomar Observatories, received the Henry Draper medal for his studies of magnetic fields in the stars and the general magnetic field of the sun. George Van Biesbroeck, Yerkes Observatory, was given the James Craig Watson medal for his work on double stars, comets, and satellites. Measurement of the ages of meteorites earned the J. Lawrence Smith medal for Mark G. Inghram of the University of Chicago's Fermi Institute.

CONFERENCE FOR COLLEGE TEACHERS OF ASTRONOMY

The astronomy department of the University of California at Berkeley will hold a conference for college and university teachers of astronomy from July 7th to August 1st. Sponsored jointly by the National Science Foundation and the university, the four-week session will be directed by Prof. Cecilia Payne-Gaposchkin of Harvard Observatory.

The conference is to consist of a series

IN THE CURRENT JOURNALS

THE ESTIMATION OF DISTANCE IN ASTRONOMY, by A. Hunter, *Journal* of the British Astronomical Association, January, 1958. "The properties of light used in measuring astronomical distances are of necessity those observed to hold terrestrially, viz. its rectilinear propagation, its inverse-square intensity decrement with distance, and its uniform velocity in empty space. It is necessary to emphasize that if these properties do not hold over cosmic distances our extrapolations will lead us astray."

TILT CRITERIA AND DIRECTION OF ROTATION OF SPIRAL GALAXIES, by G. de Vaucouleurs, *Astrophysical Journal,* March, 1958. "In conjunction with the results of all earlier discussions indicating a constant relationship between spiral pattern, obscuration dissymmetry, and spectroscopic rotation, this appears to justify the firm conclusion that normal spirals of all types and at all stages of the classification rotate with trailing arms, as was first found by V. M. Slipher nearly forty years ago."

of lectures by Mrs. Gaposchkin and members of the California faculty, as well as several research projects. The participants, limited to about 20 persons, will receive travel and living allowances. Further information may be secured from Astronomy Department, University of California, Berkeley 4, Calif.

MOUNT STROMLO REPORT

Recent progress at Mount Stromlo Observatory, Australia's major astronomical center, is described in the first annual report by its new director, Bart J. Bok. An illustrated account of the observatory appeared in the June, 1956, issue of *Sky and Telescope*.

At the beginning of 1957, the name of the institution was officially changed from the Australian Commonwealth Observatory to Mount Stromlo Observatory, and it became a part of the Australian National University.

The American astronomer Theodore Dunham, Jr., joined the staff in August and immediately began work on the design and construction of a coude spectrograph for the 74-inch reflector. This equipment will allow, for the first time, badly needed high-dispersion spectroscopic observations of southern stars.

This coude spectrograph is to be used with any one of three cameras, employing spherical mirrors of 21, 48, and 114 inches focal length. The longest camera will have a dispersion of 2.9 angstroms per millimeter, reaching 6th-magnitude stars on single-night exposures.

The observatory continues to provide the national time service, and the program of time determinations with the transit instrument has been enlarged in co-operation with the International Geophysical Year. In addition, a photographic zenith tube was put into operation in November for time and latitude-variation observations.

A Markowitz dual-rate moon camera, on loan from the U. S. Naval Observatory, has been attached to the 9-inch refractor. It is employed for precise determinations of the moon's position relative to the stars. When the results from the world-wide chain of observatories co-operating in this work during the IGY are analyzed, they will indicate irregularities in the earth's rotation, made evident by apparent irregularities in the moon's motion.

Current programs at Mount Stromlo have been summarized by William Buscombe in the April *Journal* of the Royal Astronomical Society of Canada. He gives a striking table of the varied telescopes on the mountain, some of which are the equipment of the Yale-Columbia and Uppsala observing stations. The list includes reflectors of 74, 50, 30, and 20 inches aperture, and 26-, 9-, and 6-inch refractors. There are also a 20-inch Schmidt telescope, solar tower telescope, transit instrument, photographic zenith tube, and two special cameras.

Amateur Astronomers

MIDDLE EAST CONVENTION

On April 19th, 90 registered delegates, representing 11 societies, convened for the annual meeting of the Middle East Region of the Astronomical League. It was held at West Virginia University in Morgantown, with the Fairmont Amateur Astronomers Association as host.

Early arrivals on Friday evening were treated to a planetarium demonstration by Charles Cochran, of the university faculty. After the Saturday sessions, the delegates toured the underground isotope research laboratory, guided by Charles Thomas, head of the physics department.

Of great interest to all present was the session on "Space Age." Charles H. LeRoy, Pittsburgh, Pennsylvania, reported news of MOONWATCH teams, and recordings of satellite signals were presented by the National Capital Astronomers, Washington, D. C.

At the convention banquet, the history of the 98-year-old Allegheny Observatory, Pittsburgh, was told by its director, Nicholas E. Wagman.

Regional officers elected for another term are: Dana Law, Arlington, Virginia, chairman; R. Thomas LuCaric, Baden, Pennsylvania, vice-chairman; Emil Klein, Philadelphia, treasurer; and the undersigned, secretary. The Delaware Astronomical Society will be the host for next year's convention.

BETH BEYER
77 Evans Ave.
Pittsburgh 5, Pa.

JOHN M. PIERCE DIES

One of the country's best-known amateur telescope makers passed away on March 4th at Maitland, Florida. John M. Pierce became interested in this hobby four decades ago. He worked with Russell W. Porter in organizing Stellafane, the observatory near Springfield, Vermont, where telescope makers meet annually for the Stellafane convention.

Mr. Pierce's long-continued efforts have significantly aided the growth of amateur astronomy in the United States. He contributed many articles to the telescope making column conducted by Albert G. Ingalls in *Scientific American*, and was one of the authors in the *Amateur Telescope Making* series of books. When the hobby was new and supplies were hard to get, Mr. Pierce set up a small business to provide kits and parts for his fellow amateurs.

He was active in civic affairs, and well-known as a musician and a geologist. A graduate in architectural engineering from Pratt Institute in 1910, Mr. Pierce spent all of his life as a teacher. From 1919 to 1956, he was director of the Springfield High School co-operative course, which includes training in machine-tool work, cabinet making, sheet-metal work, electricity, and auto repair.

THIS MONTH'S MEETINGS

Dallas, Tex.: Texas Astronomical Society, 8 p.m., cabin of Dr. A. J. McNeill, 7814 Forney Rd. June 23, field meeting.

Edinburg, Tex.: Magic Valley Astronomical Society, 7:30 p.m., Fireman's Park in McAllen. June 20, star party.

Orlando, Fla.: Orlando Amateur Astronomy Club, 8 p.m., Chamber of Commerce clubhouse. June 20, color motion picture, Our Mr. Sun.

Walnut Creek, Calif.: Mount Diablo Astronomical Society, 7:30 p.m., East Contra Costa Junior College. June 14, Jack Borde, "Telescope Making."

AAVSO SPRING MEETING

The island of Nantucket, Massachusetts, is to be the setting for the spring meeting of the American Association of Variable Star Observers on June 12-15.

The occasion will open the 50th-anniversary celebration of Maria Mitchell Observatory. On Saturday, June 14th, Margaret Harwood, former director, will tell about the observatory's history.

Another feature speaker will be A. E. Lilley, Yale University Observatory, who will talk on the role of rockets and radio in astronomy. There will be an exhibition of postage stamps with astronomical subjects, from the collection of Kenneth Baird, Philadelphia, Pennsylvania.

Persons who wish program time should send the titles of their papers to the AAVSO, 4 Brattle St., Cambridge 38, Mass., by June 9th. Hotel and banquet reservations should be made with Dr. Dorrit Hoffleit, Maria Mitchell Observatory, Nantucket, Mass., by the same date. Room rates at the Four Chimneys Inn will be $3.50 per person. Since single rooms are limited in number, please state if sharing a double room is acceptable.

LONG ISLAND STAR PARTIES

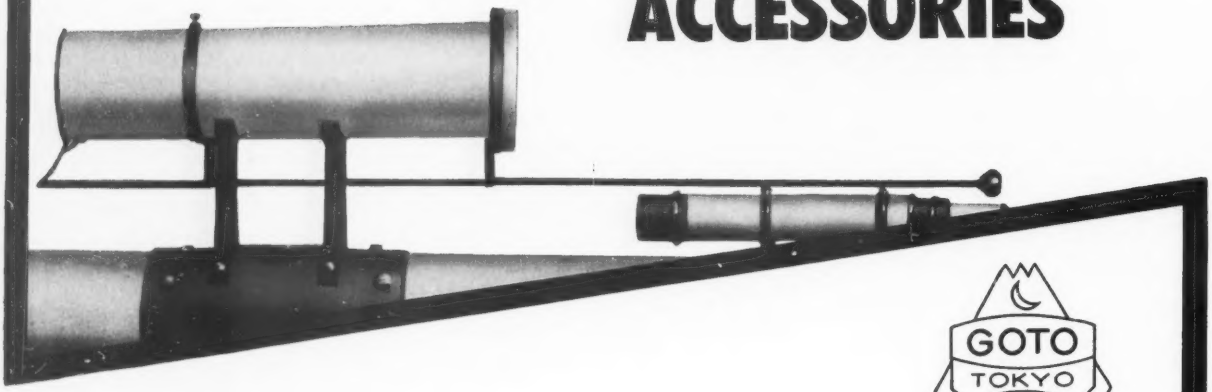
At Jones Beach State Park, on the south shore of Long Island, New York, public star parties have been held twice monthly since December. Attendance on clear evenings has ranged from 500 to 900 persons, even during the middle of winter.

Four telescopes, each manned by a trained science teacher, are used for observing the particular object under discussion. A 15-minute period is devoted to pointing out, with an auto spotlight, all the visible bright stars and constellations. On cloudy nights, special indoor programs are offered at the beach field house.

Only one meeting a month is scheduled for June, July, and August. Percy M. Proctor, 26 Mason Ave., Babylon, N. Y., is in charge of the programs, which are cosponsored by the Long Island State Park Commission and the Abraham and Straus department store in Hempstead.

GOTO'S

SUPERIOR TELESCOPIC ACCESSORIES



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The superb photograph of Comet 1957d appearing on page 568 in the October, 1957, issue of **Sky and Telescope** was taken by Mr. Alan McClure with one of these lenses.

$485.00

Sun Prominence Spectroscope

Consists of triple Amici prisms, two right-angle reversing prisms, collimator, slit mechanism with divided drum, position circle, and 25-mm. Kellner eyepiece.

When this spectroscope is used on telescopes of 4 inches or larger, solar prominences can be observed very distinctly. A spectroscope of this type is to be delivered to the Taipeh Meteorological Observatory in the near future.

$760.00

(Prices include shipping costs.)

The listed prices also include the anticipated import duties, so in making remittances 25% should be deducted from them.

Complete price lists and catalogues will be sent upon request.

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OBSERVER'S PAGE

Universal time is used unless otherwise noted.

THE SATELLITES OF SATURN

ON the evening of June 13th, the ringed planet Saturn is at opposition to the sun. During the month it will rise near sunset and remain visible throughout the night, making the season most favorable for observing this jewel of the solar system. It will be a good opportunity for the amateur to verify that a 6-inch telescope can show more moons of Saturn than of Jupiter.

Titan, brightest of Saturn's satellites, is about the same size as the planet Mercury, and may be seen in almost any amateur's telescope, even though a very large aperture is needed to bring out its disk. Rhea is an easy object, observable in a 2- or 3-inch telescope, while Dione and Tethys are not much fainter.

Iapetus shows a remarkable change in brightness as it moves around Saturn. When near western elongation it is almost as bright as Rhea, but at eastern elongation it is less than one-fifth as bright — fainter than Enceladus.

The innermost of Saturn's moons, Mimas, is so close to the planet that it is very difficult to detect when the rings are opened as widely as they are this year; Mimas is best seen when the rings are presented edge on. Hyperion and Phoebe are so faint that very large telescopes are required for their definite identification.

The accompanying chart shows the orbits of Saturn's moons (except for Iapetus and Phoebe) as they appear this month. For satellites IV to VII, the positions at various intervals after eastern elongation are indicated by the labeled tick marks.

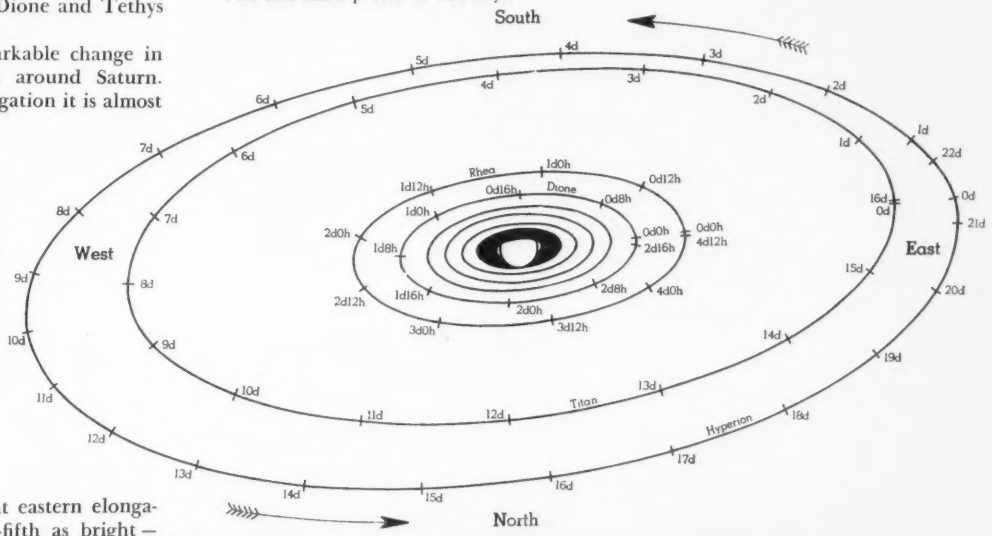
To illustrate the use of this chart, suppose that we wish to view Rhea on June 10, 1958, at 10 p.m. Eastern daylight time, which corresponds to 2^h UT on June 11th. This is $6^d\ 5^h$ after the time of eastern elongation listed in the table. This interval must be diminished by the synodic period, $4^d\ 12^h.5$, to bring it within the scope of the chart, giving $1^d\ 16^h.5$. Therefore, the position of Rhea relative to Saturn will be between the points labeled 1d 12h and 2d 0h on the plotted orbit of this satellite.

In an f/8 6-inch reflector, an average ½-inch eyepiece has a field of about 25 minutes of arc. Since even Iapetus will be within nine minutes of Saturn, it follows that any of the seven inner satellites will be in the same field as Saturn at the powers normally used.

W. E. S.

Satellite		*Mag.*	*Period*	*Date*	*Hour*	*Sep.*
I	Mimas	+12.1	$0^d\ 22^h.6$	June 1	20	0′.5
II	Enceladus	11.7	1 8.9	June 1	20	0.6
III	Tethys	10.6	1 21.3	June 1	11	0.7
IV	Dione	10.7	2 17.7	June 1	1	1.0
V	Rhea	10.0	4 12.5	June 4	21	1.3
VI	Titan	8.3	15 23.3	June 4	2	3.1
VII	Hyperion	14	21 7.6	June 17	6	3.8
VIII	Iapetus	11	79 22.1	May 20	14	9.0

This table lists the number and name of the satellite, its magnitude at mean opposition, average synodic period, the date and hour (Universal time) of a passage through eastern elongation, and the approximate maximum angular separation of the satellite from Saturn's center. The outermost moon, IX Phoebe, is about magnitude 14.5 and has a period of 524 days.



This chart from the "American Ephemeris and Nautical Almanac" gives the orbits of Saturn's satellites for this year's opposition, with south at the top, as seen in an inverting telescope. The arrows show the direction of motion in the orbits, south being the side nearer the observer.

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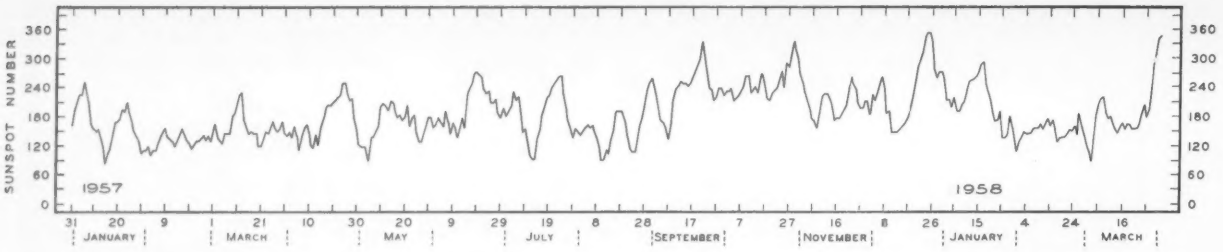

Marked variability of the sun's spottedness during an active period is summarized by this graph of Zurich daily sunspot numbers, definitive values for 1957, preliminary ones for the first three months of 1958. The yearly mean for 1957 was the highest since systematic observations began about two centuries ago. Notice the high count of 302 on March 29, 1958, when the photograph on this page was obtained. The sun continued to be active through April, as indicated by the sunspot numbers on page 430. The picture series opposite was taken during this time.

HELPFUL HINTS TO OBSERVERS!

The free literature offered in the Frank Goodwin ad below includes the following subjects: telescope observational techniques and methods; cutting down sunlight externally in viewing the sun; cleaning mirrors; sealing objectives against interelement air-space dewing; how to approximate off-axis performance with your reflector by a simple black-paper mask on mirror, occulting diffraction of diagonal and struts. (Also how the Goodwin Resolving Power lens is positively guaranteed to make any good telescope perform like a larger one, for reasons stated in the ad below.)

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The Resolving Power lens is achromatic, coated, gives flat field sharp to the edge. Here is astonishment! Price $23.50 in 4" long adapter tube fitting standard 1¼" eyepiece holders ONLY. (Also adaptable to Unitrons; state if Unitron.) Money back if not positively thrilled after two weeks trial! Used and praised by legions!

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Sunspot Count Reaches Highest Maximum

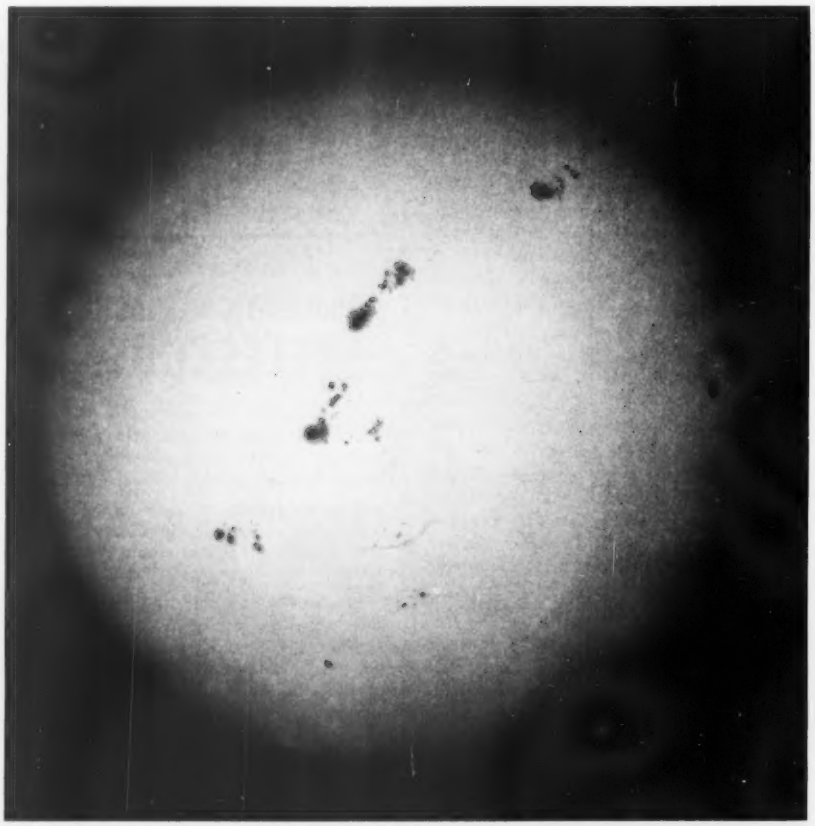
LATE 1957 saw the relative sunspot number climb to record heights. Dr. M. Waldmeier, director of Zurich Observatory which is an international clearing-house for sunspot statistics, has supplied some comparisons.

He notes that the solar activity in the second half of 1957 reached a level never before observed. During September 20-22, October 28-30, and December 22-26, the relative sunspot numbers were over 300. The highest value ever observed, 355, was reached on December 24th and 25th.

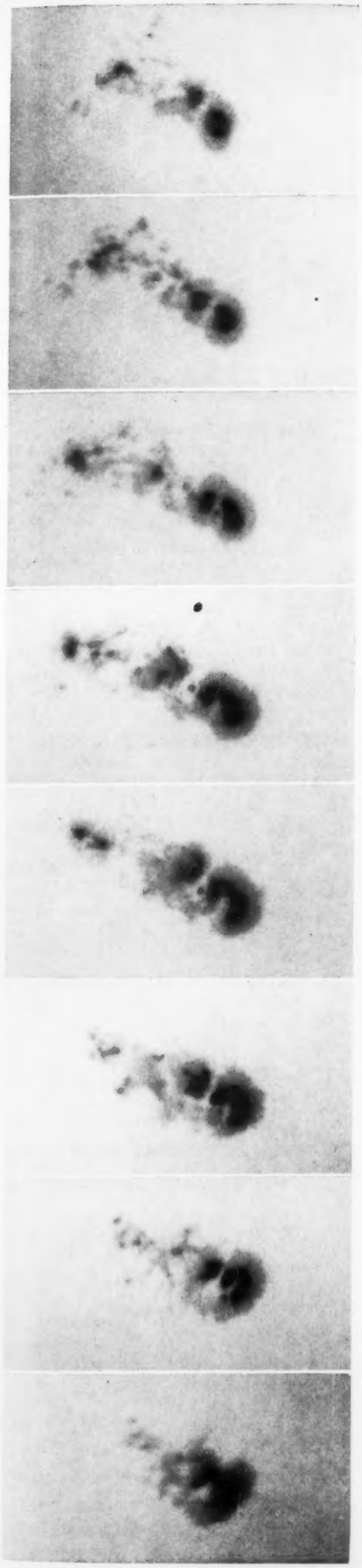
Dr. Waldmeier continues: "The previous maximum value, of 353, occurred on May 17, 1778. With 253.8, October, 1957, had the highest monthly mean ever recorded, and with 190.2, 1957 had the highest yearly mean. The next highest yearly mean, 154.4, occurred in 1778, and the third was 151.6 in 1947."

On the graph showing the daily variation of sunspot numbers, it is seen that from January, 1957, through March, 1958, the number never fell below 86 and was less than 100 only seven times. Another graph, on page 395, shows the monthly numbers since January, 1950.

Pictures of the sun taken on peak days, December 25th and October 29th, and a drawing made on December 23rd, were published in February, pages 184 and 185;



The sun had many spot groups when this photograph was taken on March 29th, at 18:29 Universal time, by Philip and Robert Del Vecchio.



Daily changes, April 17-24, 1958, in a sunspot group photographed by the Del Vecchios. Dates and Universal times, from top to bottom, are: 17, 12:49; 18, 13:05; 19, 16:00; 20, 14:25; 21, 14:45; 22, 21:50; 23, 20:35; and 24, 13:01. Toward the end of the sequence the group is breaking up.

the photographs reproduced here, by Philip and Robert Del Vecchio, Paterson, New Jersey, illustrate the sun's appearance during the present disturbed period.

DEEP-SKY WONDERS

AMONG the amateur's greatest pleasures is trying out a new and larger telescope. But it is equally thrilling to use an old instrument on a night of superb seeing, when the steadiness and transparency of the atmosphere allow the instrument to reveal more than it usually does. Perhaps the best test object for such an occasion is a star cluster or nebula.

My first view through my 10-inch reflector came one summer in Wisconsin, more than a quarter century ago. The test object was the great cluster M13 in Hercules (pictured on page 356 of last month's issue). This globular is just visible to the naked eye, at right ascension $16^h\ 39^m.9$, declination $+36°\ 33'$ (1950 co-ordinates). It is surprising that this bright an object was not discovered telescopically before Halley found it in 1714. Its diameter of 23′ is easily verified by a reflector 10 inches in aperture or larger. In the clear Wisconsin farmland skies, the cluster blazed with a glory I had never seen with my 4-inch telescope used in Milwaukee.

A short while ago the 10-inch telescope and I moved to Kansas, where the transparency of the sky is very good. On my first observing night I looked at the cluster M11 in Scutum, at $18^h\ 48^m.4$, $-6°\ 20'$. For years the 10-inch had shown this as an arrow-shaped grouping, not particularly rich in individual stars outside of the crowded central region. But here in Kansas its blur becomes a carpet of sparkling suns to the very center, with outlying stars swarming on all sides, fully confirming Barnard's estimate of 35′ for the visual diameter.

One very fine night about a year ago I turned the telescope to M4, a globular cluster nestled alongside Antares, at $16^h\ 20^m.6$, $-26°\ 24'$. Usually it looks in the 10-inch like M13 in a 2-inch or 3-inch telescope, a round unobtrusive glow with no hint of resolution into stars. However, on that exceptional night the cluster really seemed to be of its full 23′ diameter, and the glow was broken down all across the disk into individual stars. On one edge lies an irregular grouping of 9th- or 10th-magnitude stars, almost a dozen of them; elsewhere in the sky they would rank as a cluster by themselves.

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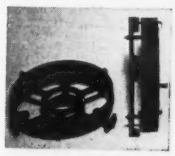

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Kits include five abrasives with our special superfine finishing abrasive for superior fine grind, selected pitch, cerium oxide, pyrex mirror, and velvet-finishing tool (heat resistant, approximate hardness of pyrex). C.O.D.'s accepted.

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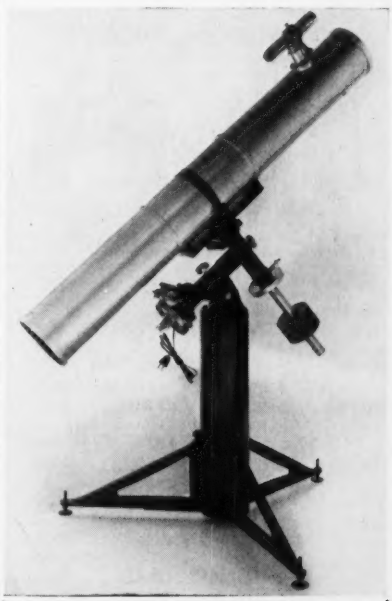

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Diameter	Focal Length	Each	Diameter	Focal Length	Each
54 mm. (2⅛")	254 mm. (10")	$12.50	83 mm. (3¼")	660 mm. (26")	$28.00
54 mm. (2⅛")	300 mm. (11.8")	12.50	83 mm. (3¼")	711 mm. (28")	28.00
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54 mm. (2⅛")	508 mm. (20")	12.50	83 mm. (3¼")	1016 mm. (40")	30.00
54 mm. (2⅛")	600 mm. (23½")	12.50	102 mm. (4")	876 mm. (34½")	60.00
54 mm. (2⅛")	762 mm. (30")	12.50	108 mm. (4¼")	914 mm. (36")	60.00
54 mm. (2⅛")	1016 mm. (40")	12.50	110 mm. (4⅜")*	1069 mm. (42-1/16")	60.00
54 mm. (2⅛")	1270 mm. (50")	12.50	110 mm. (4⅜")	1069 mm. (42-1/16")	67.00
78 mm. (3-1/16")	381 mm. (15")	21.00	128 mm. (5-1/16")*	628 mm. (24¾")	75.00
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81 mm. (3-3/16")	622 mm. (24½")	22.50	*Not coated		

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6 x 30	"ZEISS"	$18.75	16.75
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7 x 50	"ZEISS"	24.95	22.50
7 x 50	AMERICAN	32.50	—
8 x 30	"ZEISS"	21.00	18.25
10 x 50	"ZEISS"	30.75	26.50
20 x 50	"ZEISS"	41.50	39.50

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8 x 30	11.25	16 x 50	17.50
7 x 35	12.50	20 x 50	20.00

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16 mm. (⅝")	Triplet	12.50
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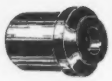

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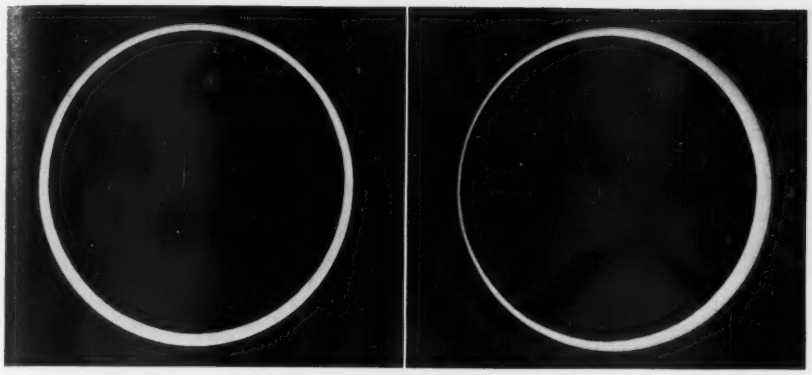


Left: In mid-eclipse, at 3:16.9 UT at Taiwan, an almost perfect annulus of sunlight was seen around the moon. Right: 3.7 minutes later, the ring had become unsymmetrical, as the moon moved eastward off the sun.

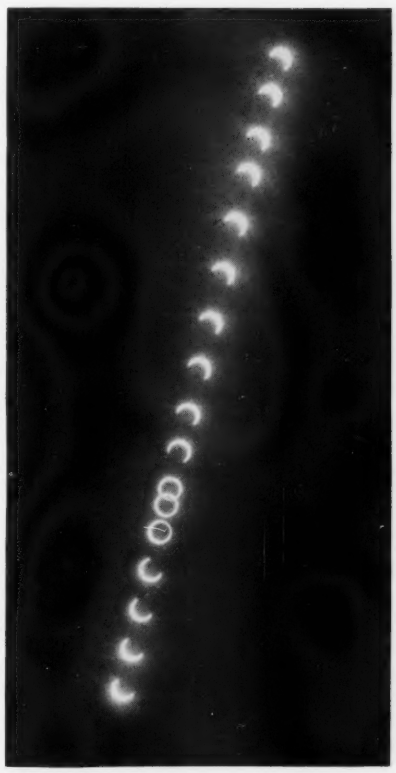
April's Annular Eclipse Observed in the Orient

At the Taipei Observatory on April 19, 1958, skies were good for observations of the annular eclipse of the sun. Chang-Hsein Tsai used a 4-inch refractor and projection through a 40-mm. eyepiece to obtain the ring-phase pictures above.

His observing location was at the northern end of the island of Taiwan (Formosa), close to the central line of the shadow path. With his own pictures Mr. Tsai sent another, by U. Y. Lai, showing the progress of the eclipse on a single photograph, reproduced at the right.

The island of Hong Kong was bisected by the northern edge of the central-eclipse path. Some 20 miles north of there, at Sheung Shui village, Hing-Chai Liu planned a sequence of 36 photographs at 10-minute intervals, but clouds interfered at times. The entire eclipse lasted more than 3½ hours, from 10:12 a.m. to 1:51 p.m.

The picture shows Mr. Liu with his



Hing-Chai Liu with the equipment he used to photograph the April eclipse.

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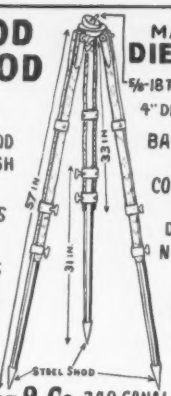

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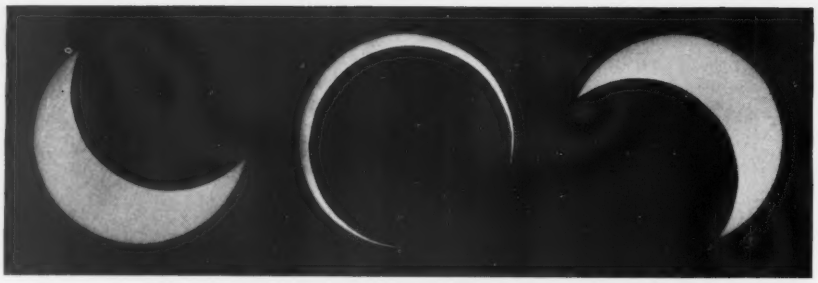

These photographs of the partial stages were taken by H. C. Liu from a point about 20 miles north of the central line of the eclipse. The times were, respectively, 11:25 a.m., 11:53 a.m., and 12:23 p.m. A solar diagonal was used to reduce the amount of sunlight gathered by the 2-inch guide telescope.

reflex camera mounted on his reflector's 2-inch guiding telescope. A 1-inch eyepiece produced a solar image 0.6 inch in diameter. With a deep red filter, exposures of 1/500 second were made on Agfa Isopan F film, developed in Promicrol. The exposure at maximum phase was 1/250 second.

A LUNAR CURIOSITY

The region on the moon to the northwest of the crater Bullialdus is rich in low-lying ridges and minor irregularities. As the sun rises there, features are seen to change while the observer watches, and many interesting configurations appear.

Robert E. Curtiss of Alamogordo, New Mexico, recorded such an appearance on the night of November 26, 1956. He had mounted a Mitchell 35-mm. motion-picture camera, loaded with Lina Shellburst panchromatic film, on a 16-inch f/6 Newtonian reflector, and was making test exposures at a rate varying from 48 to 24 frames per second. On developing the film he noticed the cross in the rough terrain to the northwest of the ring plain Fra Mauro, as shown in the photograph.

Walter H. Haas, director of the Association of Lunar and Planetary Observers, suggests that this cross may consist of some sunlit mountain spurs or ridges, and that the appearance might be of very brief duration, vanishing as the sunlight reaches the lower slopes. Observers wishing to confirm this feature should keep in mind that it probably will be visible only when the illumination closely matches that at the time Mr. Curtiss took his photographs.

In the center of this photograph by Robert E. Curtiss is a curious "cross." It lies along the terminator, the dividing line between lunar day and night. Above and to the right of the cross is the ring plain Fra Mauro, and above that the smaller, dark crater Parry. Copernicus is prominent in the lower center of the picture, and Bullialdus is at the upper right. The moon was 24½ days old.

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BOOKS AND THE SKY

GALILEO AND THE MAGIC NUMBERS

Sidney Rosen. Little, Brown and Company, Boston, 1958. 212 pages. $3.50.

EVERYONE has heard at some time about the scientific discoveries of Galileo Galilei. In this book for teenagers, Dr. Rosen tells of these achievements and their place in Galileo's life.

The story begins with Galileo's education under the guidance of his father and his subsequent introduction to mathematics at the school of Jacobo Borghini. After studying with the monks at the monastery of Vallombrosa, he enrolled at the University of Pisa, where he made his famous experiments with the pendulum and falling bodies.

Then Galileo became professor of mathematics at the University of Padua. He worked diligently on the science of machines, the laws of motion, Copernican astronomy, a temperature-measuring device of his own invention, and the supernova of 1604, which he observed night after night.

Here he also constructed his first telescopes. Dr. Rosen vividly describes the discoveries of the moon's mountains, the fainter stars of the Pleiades, and the nature of the Milky Way. Later, at Florence, Galileo observed sunspots and the phases of Venus. The rest of the volume concerns Galileo's efforts and difficulties in advancing the cause of Copernican astronomy — the truth of which his discoveries made so evident.

The book is very easy to read. The author employs dialogue frequently, allowing the reader to be on hand, so to speak, when Galileo makes his discoveries or explains them to his friends. These conversations often echo some statement actually made at the time.

On page 20, for example, Galileo's father says to him, "Do not be afraid to challenge authority at any time, if a search for truth is in question. Truth is not found behind a man's reputation. Truth appears only through the search for the answers to questions by a free mind. . . ." Similar sentiments are found in a work by his father entitled, "A Dialogue on Ancient and Modern Music."

But in one instance, on page 121, Galileo is made to say, "The Greek word for far is *tele,* and the word for see is *skopein.* I shall call this a telescope." There is no historical basis for this utterance. In view of Edward Rosen's findings in *The Naming of the Telescope* (1947), where he sorts out the conflicting evidence, Galileo cannot be given credit for inventing the name.

One minor point: Galileo's early observations of Saturn are described, then commented upon by him (page 151), "For here was Saturn with two moons accompanying it, just as Jupiter had four!" One wishes the reader were told that this was an erroneous conclusion; Galileo had actually observed the rings of Saturn but was unaware of their true nature. From the text as it is, the beginner might easily believe that Galileo had discovered two of Saturn's moons.

P. V. RIZZO
Amateur Astronomers Association
New York 24, N. Y.

THE PLANET EARTH

D. R. Bates, editor. Pergamon Press, 4 and 5 Fitzroy Sq., London W. 1, England, 1957. 312 pages. 35s.

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SKY AND TELESCOPE BACK ISSUES

Unless otherwise specified, the previous numbers of *Sky and Telescope* to which references are made in articles and departments are available at 50 cents per copy. Since January, 1955, only the issues of January, February, October, and November, 1956, and that of January, 1957, are out of print. Many issues before January, 1955, are available; write for information on particular copies.

A few bound sets of Vol. XV (November, 1955, to October, 1956) and Vol. XVI (November, 1956, to October, 1957) are available, in blue library buckram, at $12.50 each, while the supply lasts.

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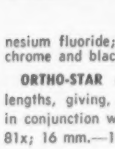

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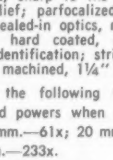

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RALPH S. BATES
State Teachers College
Bridgewater, Mass.

NEW BOOKS RECEIVED

THEORETICAL ASTROPHYSICS, *V. A. Ambartsumyan*, editor, 1958, *Pergamon*. 645 pages. $22.50.

First published in Russian in 1952, this advanced textbook by Soviet astrophysicists has been thoroughly revised by the original authors, Professor Ambarzumian, E. R. Mustel, V. V. Sobolev, A. B. Severny, and S. B. Pikelner. The English translation is by J. B. Sykes.

THE TELESCOPE, *Harry Edward Neal*, 1958, *Messner*. 192 pages. $3.50.

For beginning astronomers, this book tells something about telescopes and the people who build and use them. It lists the locations of 35 of the world's largest instruments.

THE ENCYCLOPAEDIA OF RADIO AND TELEVISION, 1958, *Philosophical Library*. 736 pages. $12.00.

Arranged in dictionary form, this volume discusses radio and television terminology briefly and simply for the novice as well as the advanced worker. It contains over 3,000 entries and nearly 800 illustrations. An appendix adds new developments since the book was first published in 1950.

TEACHING SCIENCE TO THE ORDINARY PUPIL, *K. Laybourn* and *C. H. Bailey*, 1957, *Philosophical Library*. 415 pages. $10.00.

Two British educators, one the head of the science department in a teachers training college, describe with text and diagrams 536 simple experiments, using only ordinary household materials, for secondary school instruction. The devices illustrate basic points in biology, physics, chemistry, optics, and astronomy.

ATLAS OF THE SKY, *Vincent de Callatay*, 1958, *St. Martin's Press*. 157 pages. $12.50.

Originally published in French as *Atlas du Ciel*, in 1955, this translation is by Sir Harold Spencer Jones, former Astronomer Royal of England. The same 36 large white-on-black maps, showing northern and southern stars down to the 5th magnitude, are now accompanied by English commentaries. The atlas also includes 45 complementary key charts.

THE BLACK CLOUD, *Fred Hoyle*, 1957, *Harper*. 251 pages. $2.95.

This science-fiction novel by an outstanding British astronomer tells what might happen if a great cloud of interstellar gas were to move between the earth and the sun.

PLANETS, STARS AND SPACE, *Joseph Miles Chamberlain* and *Thomas D. Nicholson*, 1957, *Creative Educational Society*, Mankato, Minn. 223 pages. $7.50.

Prepared by two staff members of the American Museum-Hayden Planetarium, this book for the young reader offers a quick survey of celestial objects, from the earth to the outer galaxies. There are about 100 full-page illustrations, and the accompanying descriptions, set in large type, are informative and easy to read.

AN INTRODUCTION TO THE STUDY OF STELLAR STRUCTURE, *S. Chandrasekhar*, 1957, *Dover*. 509 pages. $2.75, paper bound.

Advanced students will welcome this inexpensive reprint of a famous textbook on the internal constitution of the stars, first published in 1939 under the same title by the University of Chicago Press.

APPLIED OPTICS AND OPTICAL DESIGN, *A. E. Conrady*, 1957, *Dover*. 518 pages. $2.95, paper bound.

For over a quarter century this book has been widely used by telescope designers, and is now available in reprint form. The author states in the preface: "The present volume includes all the ordinary ray-tracing methods, the general theory of perfect optical systems, the complete theory of the primary aberrations, and as much of the higher aberrations as is required for the design of all types of telescopes, of low-power microscopes, and of the simplest photographic objectives."

ADVANCES IN GEOPHYSICS, Vol. 4, *H. E. Landsberg* and *J. Van Mieghem*, editors, 1958, *Academic Press*. 456 pages. $12.00.

Since 1952 this series has been the medium for technical summaries of geophysical studies in which important progress is made. In this volume, Joseph W. Chamberlain writes on theories of the aurora, L. LaPaz on the effects of meteorites on the earth, and P. J. Melchior on earth tides. Other contributions deal with atmospheric chemistry and with the statistical problem of smoothing time series. Each section has an extensive bibliography.

EARTH, MOON AND PLANETS, *Fred L. Whipple*, 1958, *Grosset and Dunlap*. 293 pages. $2.95.

This popularly written, yet authoritative account of the larger bodies in our solar system first appeared in 1941, as one of the Harvard Observatory books on astronomy. The author, now director of the Smithsonian Astrophysical Observatory, has made few changes in this new printing, but in the preface he lists the most significant advances of recent years.

THE ASTRONOMICAL UNIVERSE, *Otto Struve*, 1958, *University of Oregon Press*. 55 pages. $1.50, paper bound.

This strikingly illustrated pamphlet contains the text of the Condon lectures Dr. Struve gave in Oregon last year, dealing with the solar system and with stellar evolution. It presents an up-to-date orientation in astronomy for the layman.

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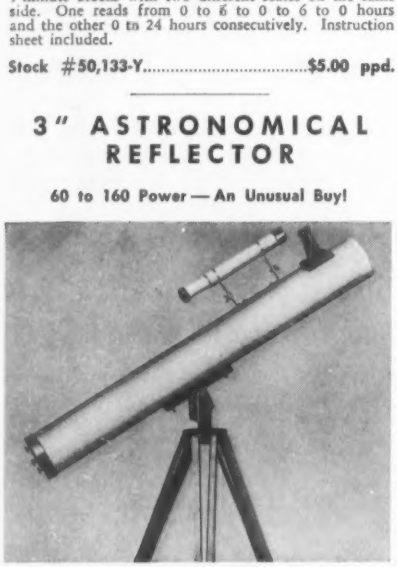

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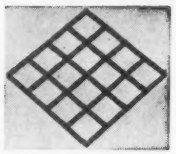

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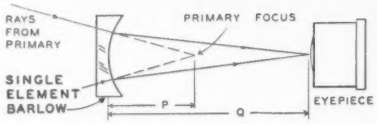

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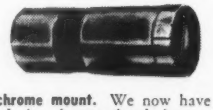

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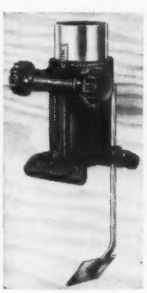

For Reflectors

For Refractors

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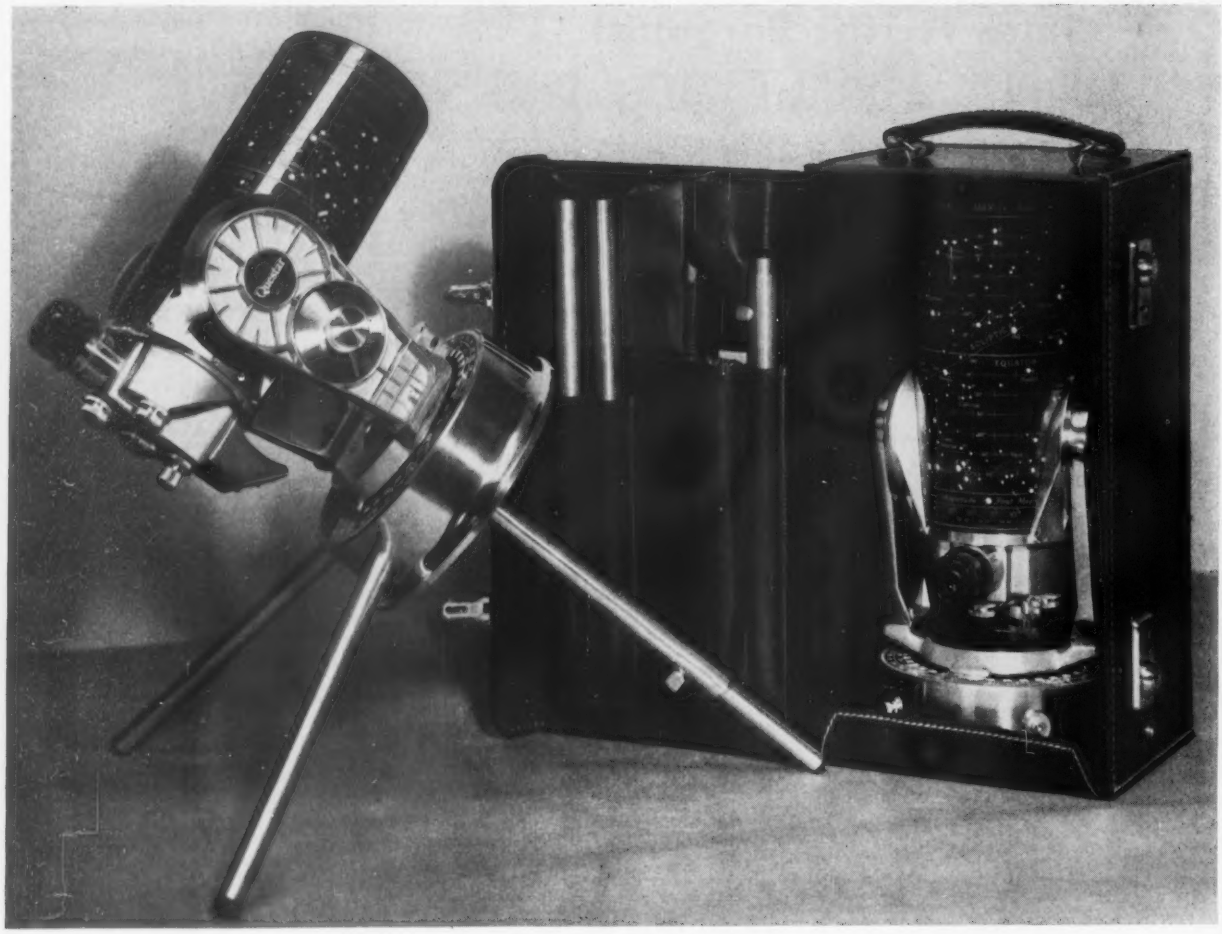

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You seat yourself before the table on which it stands. You have placed the chair just so, to be sure you sit comfortably. For that is the whole idea — to be so completely unstrained and relaxed that you can concentrate on the prime business of seeing. We don't want anything to interfere with your keenest sight; we want your vision to stay at its best. So put your elbows on the table. Go ahead, use the table — sprawl around all you want to, just so you are comfortable. Support your head on your hand, or maybe cup your palm over the eye you are not using, while keeping it open without distracting light or the necessity to squint.

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This comfortable attitude is possible only because Questar is the shortest of telescopes. It is all in one piece, too, for traveling in altazimuth form, so you escape the major problems of toting and setting up. The only assembly needed is to thrust home the three machined legs into their honed sockets, which raises the instrument into polar-equatorial position. In less than a minute you can get Polaris into the finder and be in business, with the smooth synchronous driving mechanism ticking over.

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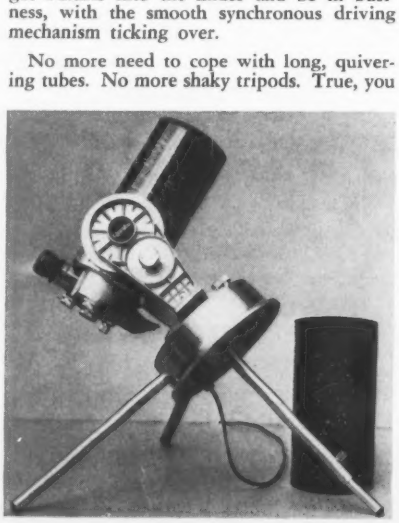

No more standing on ladders. No more standing on your head to use a finder — you needn't move your head. We could go on and on about the disadvantages of long-tubed, single-purpose telescopes, but you probably know them only too well.

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Ooops — sorry! In our April advertisement "Preview," the delivery date of the Questar 7-inch should have read "late '58" not "late '59."

GLEANINGS FOR ATM's

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Notes and New Data on Maksutov Telescopes

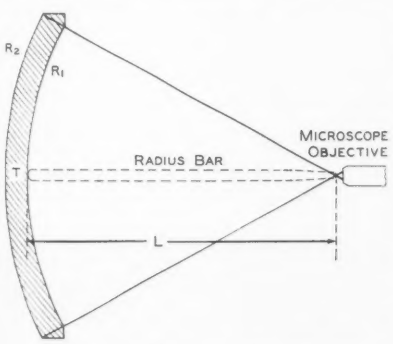
Convex radius measurements. With the tester described in the April issue, radius measurements cannot be accomplished directly on the convex surface of an optical element. It was suggested then that such work be done against concave masters, testing by interference of light between the surface being figured and the master surface.

However, John Gregory, Springdale, Connecticut, whose specifications for Cassegrainian-Maksutov telescopes of focal ratios f/15 and f/23 appeared in this department for March, 1957, reminds us that the Foucault testing of a Maksutov correcting lens' convex surface is done through the glass. He suggests it should likewise be possible to make a radius reading on the testing machine if we allow for refraction and the thickness of the glass. He supplies the formula:

$$R_2 = T + n/[1/L + (n - 1)/R_1],$$

where R_2 is the radius of the central zone of the convex surface, **T** the central or axial thickness of the lens, **n** the refractive index of the glass for sodium light, **L** the distance from the center of the R_1 surface to the image formed by the central zone of the R_2 surface.

To carry out this test, a radius bar is placed in contact with the center of R_1, as shown in the diagram, and **L** is measured. The radius bar for the R_1 surface cannot be used, for the R_2 image is significantly nearer the lens, and a new, shorter bar must be made. For the Gregory 6-inch f/15 design its length should be 6.231″, for the f/23 7.748″. Note that **L** is calculated for the central zone of the convex surface, not for the average cutoff distance of the knife-edge test, which in the 6-inch f/15 design would be 0.0006″ shorter. But the tolerances on these radii of curvature are a hundred times greater than this, so the difference is not too serious.



A radius tester set up for measuring the convex surface of an f/15 Gregory-Maksutov lens through the concave side. If the thickness of the glass is 0.541″, then the radius bar's length should be 6.231″ to match the convex surface's radius of curvature of 6.888″.

Actual working tests of this method are needed to determine whether or not it can be used throughout the final grinding stages of the convex surface. It may be that too high a polish will be necessary and a "quick shine" will not be sufficient. On the finished lens, however, testing R_2 through R_1 can provide a valuable safety check.

Gregory-Maksutov design changes. Mr. Gregory has made some slight, but important, alterations in the figures for his f/15 instrument (see *Sky and Telescope*, March, 1957, page 236), commenting:

"The original design brought C and F light to a common focus for paraxial rays only, and in the 6-inch size chromatic aberration at the edge zone was close to the allowable limit. With 8- and 10-inch blanks now available, I thought it worth while to recalculate to bring C and F together near the 0.7 zone, which will give the best color correction. But if you have a 6-inch already polished out, keep going, for you will never see the difference in that size."

The changes in Mr. Gregory's 6-inch f/15 design are listed here, all figures in inches, with the original tolerances still applying:

Symbol	*Original*	*New*
T_c	0.541	0.520
R_3	−30.83	−29.42
S	12.867	12.110
BFL	17.16	18.70

The first change reduces the lens thickness a small amount and requires only a little more rough grinding. The change of R_3, the primary mirror radius of curvature, involves removing about 0.008″ more glass; this can be done in the late carborundum stages if work has already begun. The decrease in **S**, separation of lens and mirror, shortens the over-all tube length ¾″; the back focal length is 1½″ longer. This is an aid to those who wish to put a diagonal prism immediately behind the mirror cell to bring the image beyond the edge of the tube for easy viewing of objects near the zenith, as seen in the picture on page 361 of *Amateur Telescope Making — Book Two.*

To check R_2 on the radius tester, the radius bar for the altered design should have a length of 6.263″.

Norman-Maksutov alternate design. Burt A. Norman, Franklin Centre, Quebec, has also made some modifications in the design of his Newtonian-Cassegrainian Maksutov, for which specifications were given in December, 1957, page 96, and he sends the following information:

"In the compound telescope there are two commonly used methods of correct-

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You will get the best possible performance from your telescope with one of our clear **fused quartz** diagonals. Accuracy guaranteed 1/20 wave.

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ing the spherical aberration at the secondary focus. If the primary system has already been corrected, the secondary for a Cassegrainian must be made hyperboloidal, as in my original design. The other method is to undercorrect the negative aberration of the primary mirror so that it just balances the positive aberration of a spherical secondary, as in the Dall-Kirkham design.

"In the Maksutov telescope, a spherical secondary mirror is conveniently obtained by aluminizing a spot on the back (R_2 surface) of the correcting lens. The curvature of the primary mirror may then be increased to provide enough aberration to overcome that of the secondary spot."

Mr. Norman has found a way of using this system for the Newtonian-Cassegrainian design, by careful adjustment of the radius of curvature of the primary mirror and its distance from the corrector. The result is a telescope similar in design to Mr. Gregory's f/23.

Such a system produces a shorter instrument, there is no secondary surface to make, no spider diffraction in the Cassegrainian arrangement, and greatly improved correction of coma at the Cassegrainian focus. Aluminizing the spot on the back of the lens would not interfere with its use in the original design, as it would be obscured by the diagonal or independent secondary. Mr. Norman continues:

"The 11-inch version was carefully ray-traced in sodium light and gives only 0.070″ spherical aberration against a permissible 0.222″. Coma in the new system is only 0.0006″, whereas 0.0025″ is permissible. The three spherical surfaces should require no retouching in the completed instrument."

Except for the characteristics listed below, the values given for the 11-, 8- and 6-inch instruments remain as given in December, 1957. All dimensions are in inches:

CA	11.0	8.0	6.0
D_s	2.1	1.5	1.1
R_3	−87.250	−63.454	−47.591
R_4	−17.747	−12.907	−9.680
S	36.988	26.900	20.170
BFL	46.899	34.108	25.581
EFL	268.8	195.5	146.6
EFR	24.44	24.44	24.44

In discussing these changes, we need consider only the 11-inch instrument, as it was analyzed in Mr. Norman's December article. A decrease in D_s, the diameter of the Cassegrainian secondary, from 2.88″ to 2.1″ will help reduce diffraction from the central obstruction. The mirror radius shortens about 7¼″, while the radius of the secondary, R_4, becomes equal to R_2, the lens surface on which it is placed by aluminizing. Although the back focal length shortens more than an inch, the new position of the secondary surface keeps the distance of the Cassegrainian focus behind the primary mirror about equal to that in the original design. The effective focal length is quite long, more than 22′, but this is satisfactory for lunar and planetary observing.

Mr. Norman has come up with an excellent design, and the possibility of constructing a "convertible" Maksutov should appeal to the advanced amateur. Either by interchanging primary mirrors in the same tube, or by having two separate tubes and interchanging the corrector, it should be possible to observe with either an f/4.2 Newtonian visual and semi-wide-field reflector or a high-powered Cassegrainian instrument. With coma correction many times reduced from that obtained with a hyperboloidal secondary, this new design should prove greatly superior in performance to the old one.

Tables for computing. Few amateurs have access to desk calculating machines, and find the extraction of roots and other computing needed for work on compound telescopes quite laborious. Even a table of six-place logarithms is often not accurate enough. For those who like to check optical designs, a very useful book is *Barlow's Tables,* edited by L. J. Comrie, Chemical Publishing Co., New York, 1954, $3.95. It contains squares, cubes, square roots, cube roots, and reciprocals of integers from 1 to 12,500, tabulated to seven decimal places.

R. E. C.

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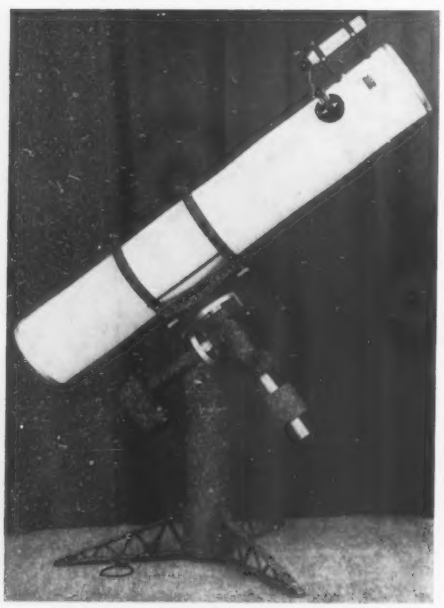

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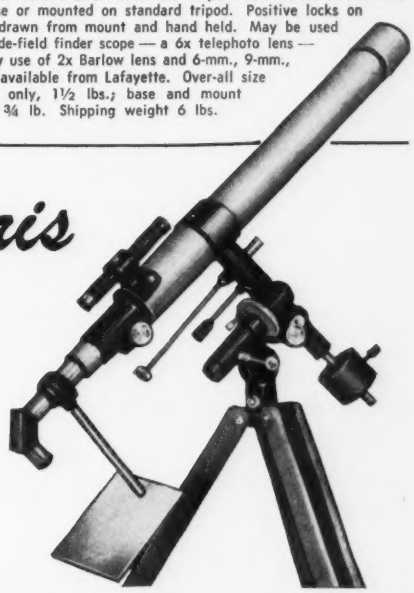

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- Exclusive Two-way Pier-tripod — a massive 45-pound pier for permanent installation

A 10-INCH REFLECTOR WITH A PASADENA MOUNTING

FOUR YEARS of spare-time work were required to make my 10-inch telescope, which at first glance looks like a Springfield type. Actually, it is the Pasadena mounting invented by the late F. M. Hicks, whose picture with his original instrument appears on page 263 of the 1928 edition of *Amateur Telescope Making*. Further examples of this type of mounting are illustrated on page 351 of the 1950 edition. Long ago I received blueprints and helpful data from Mr. Hicks. After a lapse of some time, I resumed activity a few years ago.

The focal length of my telescope is nearly 86 inches, and the image is brought to the eyepiece by two pyrex diagonals in the same manner as with a Springfield. The bronze eyepiece holder has $1\frac{1}{2}$" of 20 threads per inch, which provides excellent helical focusing. The tube, welded from sheet steel, provides the great rigidity needed for the long overhang. The counterweight shaft is $1\frac{1}{4}$" cold-rolled steel, and is bolted through the tube to an internal shell of 3/16" steel plate which extends well back into the portion of the tube carried in the saddle of the mounting.

Delicate balancing of the tube and counterweight (total weight about 200 pounds) permitted operation of the former hand drive with the tip of one finger. Only very slight friction was thus needed on the polar-axis ring-drive gear, and the telescope can be rapidly swung to any position, even while the new motor drive is running. The latter has a 40-to-1-reduction worm and gear, attached to the shaft of the hand drive with a friction coupling, and a small 5-r.p.m. motor is used. This combination gives a sidereal driving rate, the hand drive providing a slow-motion control.

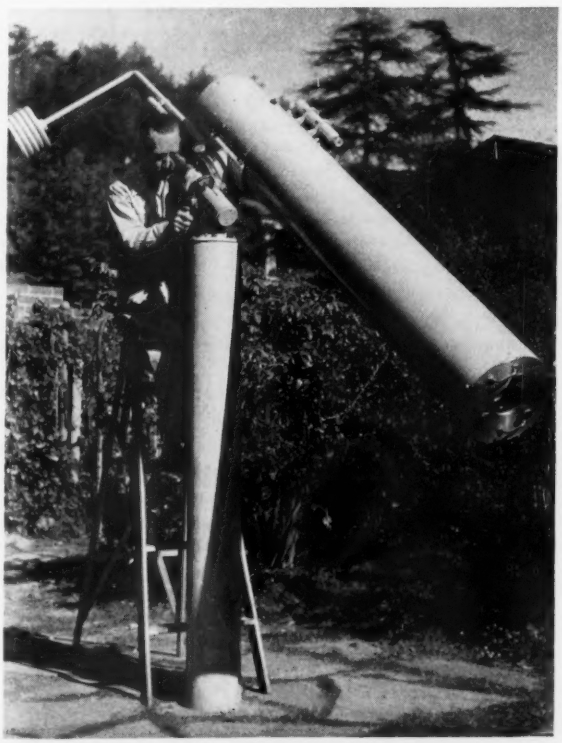
The pier is 8" steel well-casing, filled with concrete and sunk several feet into the ground, where it is anchored with about 300 pounds of concrete resting on bedrock. This is so solid that even under high powers the image will settle within about two seconds after a hard blow on the pier itself.

All the optical parts are mounted in carefully machined and keyed cells. This makes it possible to remove and replace them without destroying the collimation; only the eyepiece holder and its diagonal need to be checked.

As my home is located in the Los Feliz Hills near the Griffith Observatory, my biggest observing problem comes from the night lights and smog of Los Angeles. Some improvement is experienced after midnight.

G. L. McFARLAND
2421 Glendower Ave.
Los Angeles 27, Calif.

This closeup of the equatorial head of the McFarland telescope shows the assembly by which light from the primary mirror is reflected out of the main tube along the declination axis, thence at right angles northward along the polar axis to the eyepiece, which remains in a fixed observing position.



G. L. McFarland at the eyepiece of his 10-inch reflector. A permanent housing is planned, although the instrument is well covered when not in use. This observing location has its disadvantages, as the lights of the city of Los Angeles prevent work on stars more than 25 degrees south of the celestial equator.

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With this 4" UNITRON, you have at your disposal a complete range of magnifications: 25x, 38x, 60x, 83x, 120x, 167x, 214x, 250x, 300x, 375x. And with the Super-UNIHEX Rotary Eyepiece Selector, by a flick of a finger, you can switch from a spectacular wide-field view of the sky to high-power observation of planetary details.

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See the back cover.

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eyepieces for 250x, 214x, 167x, 120x, 83x, 60x, 38x

4" **EQUATORIAL** with clock drive **$985**
(**$98.50 Down**), Model 160V, eyepieces as above

4" **EQUATORIAL** with clock drive and metal **$1075**
pier (**$107.50 Down**), Model 166V, eyepieces as above

4" **PHOTO-EQUATORIAL** with clock drive and **$1175**
Astro-camera (**$117.50 Down**), with eyepieces
for 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x

4" **PHOTO-EQUATORIAL** with clock drive, pier, **$1280**
Astro-camera (**$128.00 Down**), eyepieces for 375x,
300x, 250x, 214x, 167x, 120x, 83x, 60x, 38x, 25x

6" **EQUATORIAL** with clock drive, pier, **$5125**
2.4" view finder, with eyepieces for 625x, 500x,
416x, 357x, 277x, 200x, 138x, 100x, 62x, 42x

6" **PHOTO-EQUATORIAL** as above but with **$5660**
4" guide telescope, illuminated diagonal,
UNIBALANCE, Astro-camera Model 330

6" **PHOTO-EQUATORIAL** as above with **$6075**
addition of 3" Astrographic Camera Model 80

There is much to recommend a UNITRON Refractor as the logical choice for the amateur astronomer. Optically speaking, a UNITRON duplicates the performance of larger telescopes of other types. With its long focal length, higher magnifications of planetary and lunar images are obtained with low-power eyepieces. Moreover, there are no mirrored surfaces to become oxidized, no components which require periodic alignment, no secondary optics to cause diffraction patterns, and no folding of the light back on itself through turbulent air with consequent loss of definition. No wonder that you see more and see better with a UNITRON — the telescope that has withstood the test of time.

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Here is an instrument designed in every way to meet the exacting requirements of serious astronomical research — a custom-built telescope in every respect except the price tag. UNITRON's 6" is the logical choice for the serious observer and for the school and college observatory. There are three basic models to choose from. Whether your major interests lie in visual work or visual observing and astrophotography, there is a UNITRON 6" for you — the INVESTMENT OF A LIFETIME FOR A LIFETIME. Write for Bulletin No. 6.

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Do not hesitate to use this plan merely because you have never before purchased anything on time payments. The procedure is practically painless and is an ideal means of enjoying the use of your UNITRON while paying for it.

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UNITRON ACCESSORIES include objective lenses, eyepieces, rack-and-pinion focusing mechanisms, sun projecting screens, guide telescopes, the UNICLAMP camera brackets, and many other components in addition to those listed on this page. All are described, illustrated, and priced in the new UNITRON Catalog. Since each component is used as standard equipment in UNITRON Refractors themselves, you are assured of obtaining the finest quality.

ASTRO-CAMERA 220: Complete with air-operated curtain shutter, giving speeds of 1/10 to 1/90 second, bulb and time, shutter release, ground-glass back, 3 double plateholders for 3¼" x 4¼" plates or cut film, a 30-mm. f.l. eyepiece, extension tubes and clamps, and a fitted wooden cabinet. Model A is designed to fit the UNITRON rack and pinion and is for UNITRONS only. Model B fits 1¼" eyepiece holders. A or B:

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1. **VIEW FINDER** (As used on UNITRON 2.4" Models): 23-mm. (.93") achromatic objective, 6x eyepiece with crosshairs. Chromed brass tube. Mounting brackets with centering screws.

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3. **VIEW FINDER (As illustrated on facing page):** 42-mm. (1.6") coated achromatic air-spaced objective. 10x eyepiece with crosshairs. Duraluminum tube finished in white enamel. Dewcap. Furnished with mounting brackets with centering screws for collimation. This finder also makes an excellent hand telescope for spectacular wide-field views of the sky.

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SUNSPOT NUMBERS

The following American sunspot numbers for March were derived by Dr. Sarah J. Hill of Whitin Observatory, Wellesley College, from AAVSO Solar Division observations.

March 1, 120; **2,** 114; **3,** 159; **4,** 186; **5,** 214; **6,** 212; **7,** 145; **8,** 182; **9,** 173; **10,** 171; **11,** 162; **12,** 163; **13,** 166; **14,** 200; **15,** 166; **16,** 169; **17,** 171; **18,** 151; **19,** 168; **20,** 144; **21,** 160; **22,** 166; **23,** 191; **24,** 208; **25,** 189; **26,** 233; **27,** 243; **28,** 237; **29,** 287; **30,** 278; **31,** 268. Mean for March, 187.0.

Below are observed mean relative sunspot numbers from Zurich Observatory and its stations in Locarno and Arosa.

April 1, 290; **2,** 292; **3,** 245; **4,** 245; **5,** 244; **6,** 212; **7,** 246; **8,** 246; **9,** 204; **10,** 197; **11,** 159; **12,** 140; **13,** 127; **14,** 96; **15,** 99; **16,** 108; **17,** 147; **18,** 168; **19,** 191; **20,** 192; **21,** 218; **22,** 212; **23,** 201; **24,** 181; **25,** 206; **26,** 182; **27,** 190; **28,** 198; **29,** 207; **30,** 208. Mean for April, 195.0.

CELESTIAL CALENDAR

Universal time is used unless otherwise noted.

MOON PHASES AND DISTANCE

Full moon	June 1,	20:55
Last quarter	June 9,	6:59
New moon	June 17,	7:59
First quarter	June 24,	9:44
Full moon	July 1,	6:04

	June	Distance	Diameter
Apogee	11, 5^h	251,300 mi.	29′ 33″
Perigee	26, 9^h	229,200 mi.	32′ 24″
	July		
Apogee	8, 23^h	251,100 mi.	29′ 34″

MINOR PLANET PREDICTIONS

Minor planet predictions for this month appeared on page 379 of the May issue.

VARIABLE STAR MAXIMA

June 2, R Canum Venaticorum, 134440, 7.7; 6, R Caeli, 043738, 8.0; 7, RS Herculis, 171723, 8.0; 7, T Centauri, 133633, 6.1; 14, R Virginis, 123307, 6.9; 22, RS Scorpii, 164844, 6.8; 22, T Hydrae, 085008, 7.7; 24, R Pegasi, 230110, 7.9.

July 5, T Herculis, 180531, 8.0; 6, RT Cygni, 194048, 7.4; 8, W Lyrae, 181136, 8.0.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

FILM FOR NAKED-EYE SUNSPOT OBSERVING

Recently there have been several references in *Sky and Telescope* to naked-eye sunspot observing. The filter I have found most satisfactory for this purpose is *undeveloped* Verichrome Pan film, as it is quite dense. This film can be bought in the 120 or 620 size and mounted in 2¼-inch square Easymounts for convenience in use. When the sun is near the horizon or dimmed by light haze, undeveloped Panatomic-X or unexposed but developed Kodachrome is useful.

Using these films, it is possible to observe the largest sunspots, and by successive observations to note the sun's 25-day rotation. RICHARD SUMNER

Selkirk, N. Y.

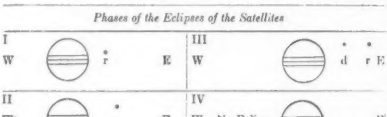
JUPITER'S SATELLITES

The configurations of Jupiter's four bright moons are shown below, as seen in an astronomical or inverting telescope, with north at the bottom and east at the right. In the upper part, *d* is the point of disappearance of the satellite in Jupiter's shadow; *r* is the point of reappearance.

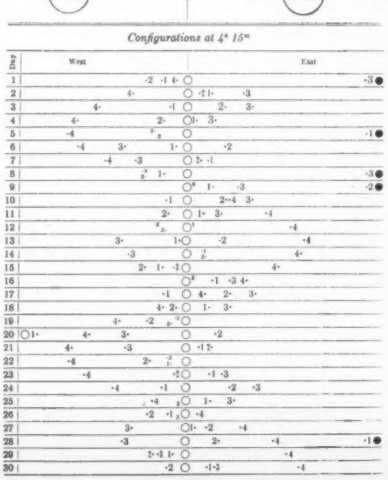
In the lower section, the moons have the positions shown for the Universal time given. The motion of each satellite is from the dot toward the number designating it. Transits over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the *American Ephemeris and Nautical Almanac.*

JUNE

Phases of the Eclipses of the Satellites



Configurations at 4^h 15^m



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Classified advertising costs 25 cents a word, including address; minimum charge, $3.00 per ad. Only one *for sale* ad per issue for each advertiser. *Remittance must accompany order.* Insertion is guaranteed only on copy received by the 20th of the second month before publication; otherwise, insertion will be made in next issue. We cannot acknowledge classified ad orders. Sky Publishing Corporation assumes no responsibility for statements made in classified ads, nor for the quality of merchandise advertised. Write Ad Dept., *Sky and Telescope,* Harvard Observatory, Cambridge 38, Massachusetts.

FOR SALE: Eyepiece holders, $5.00; spiders, $7.00. Merle Welander, Rte. 3, Stillwater, Minn.

6″ REFRACTOR for sale. Equatorial mount, setting circles, 6 eyepieces, pier. Very rigid. Tommy May, P. O. Box 483, Arlington, Tex.

TELESCOPE OBJECTIVE for sale. 6″ diameter, air-spaced achromat, coated, focal length 93.68″, finest quality, unmounted, $300.00. M. Laikin, 8728 Stewart-Gray Rd., Downey, Calif.

OBSERVING FLASHLIGHT: Excellent for consulting reference material. Separately shielded red and clear bulbs. Uses standard flashlight batteries (not included). Postpaid $5.50. Nathan Ayer, 3277 Massachusetts Ave., Lemon Grove, Calif.

SELL or trade: 8″ reflector, professional, new condition. Want refractor. William Bronks, 4314 Ave. I, Brooklyn 10, N. Y.

WANTED: Corrector blank for Maksutov, 8″ or larger. A. Presnell, 3315 Queen City Ave., Cincinnati 38, Ohio.

SIDEREAL DRIVE for telescope or camera, track stars accurately, simple gearless design, make transparencies, complete plans, $1.00. "Space Chart," planets, sun, moon, asteroids, stars, constellation maps, $1.00. L. Mussgnug, Box 74, Bethel, Conn.

DE LUXE Dynascope, same as on page 380, May issue. Barlow lens, rotating tube. Carroll E. Beatty, 8397 Archdale, Detroit 28, Mich.

TELESCOPE TUBING: Aluminum, 2″ through 8″ diameter, any length. Pesco-A, Box 363, Ann Arbor, Mich.

EQUATORIAL MOUNTS: Four sizes, $21.95 to $74.95. Free literature. Marvin Stell, 600 E. 5th, Coleman, Tex.

FINE ANASTIGMATS, barrel mounts, iris: 200-mm. f/2.9, $37.50; 300-mm. f/2.5 (no iris), $115.00; 350-mm. f/5.6, $39.50; 500-mm. f/6.3, $59.50; 750-mm. f/6.3, $79.50. Walter Baer, 741 State St., Lancaster 2, Pa.

BEGINNER'S Telescope Kit: $3.00 each, all parts, and 3 lenses. Make 8-power astronomical telescope. Perfect for youngsters and school projects. Frank Myers, 19200 N. Park Blvd., Shaker Heights, Ohio.

4″ UNITRON, equatorial mount, slow-motion controls, with 2.4″ photographic guide telescope, astro-camera, sun projection screen, 7 eyepieces, storage cabinets. Sacrifice, $760.00. Walter Lindemann, 100 Findlay Ave., Tonawanda, N. Y.

"SATELLITE PATHFINDER," an ingenious device designed at the American Museum-Hayden Planetarium to help predict Northern Hemisphere passages of artificial satellites. $1.95 postpaid. Send to Box C, *Sky and Telescope,* Harvard Observatory, Cambridge 38, Mass.

METEORITES: $1.00, $3.00, $10.00, $14.00. Equatorial mount and tripod to accommodate 6″ reflector, $15.00 f.o.b. Scientific Laboratory, 2846 Oakley Ave., Baltimore 15, Md.

EKTAR 12″ f/2.5 lens, coated, $68.00 (cost $600.00). J. Jones, 7555-31 Ave. NE, Seattle 15, Wash.

GEIGER COUNTER. Inexpensive. Make your own. Pamphlet tells how to make five easy circuits. Excellent for counting cosmic rays, prospecting, school science project. Send $1.00 to Trans-Space Laboratory, Box 111, Princeton Junction, N. J.

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RECESSION SALE: Parabolic 8″ f/8 or f/12 mirrors, ⅛-wave correct, perfect edge, zone free, and aluminized. Offer for limited time only. Postpaid in U. S. A., only $50.00. Complete catalogue, 25¢. Quality Optics, Walbridge, Ohio.

QUESTAR: Field model, all accessories, finder, de luxe equatorial mounting, new. Reasonable. Sol Saul, 3 Theodore Dr., Bethpage, N. Y.

ASTRONOMICAL BOOKS, used and new. Science for young folks — satellites, spaceflight, Mars. Rasmussen and Reece, 6 Guy Park Ave., Amsterdam, N. Y.

BOOKLET for sale: Explains amateur telescope operation including setting circles, alignment, orientation, sidereal time, what to observe, 44 pages, $1.00. Ray Dudley, 28503 Saddle Rd., San Pedro 23, Calif.

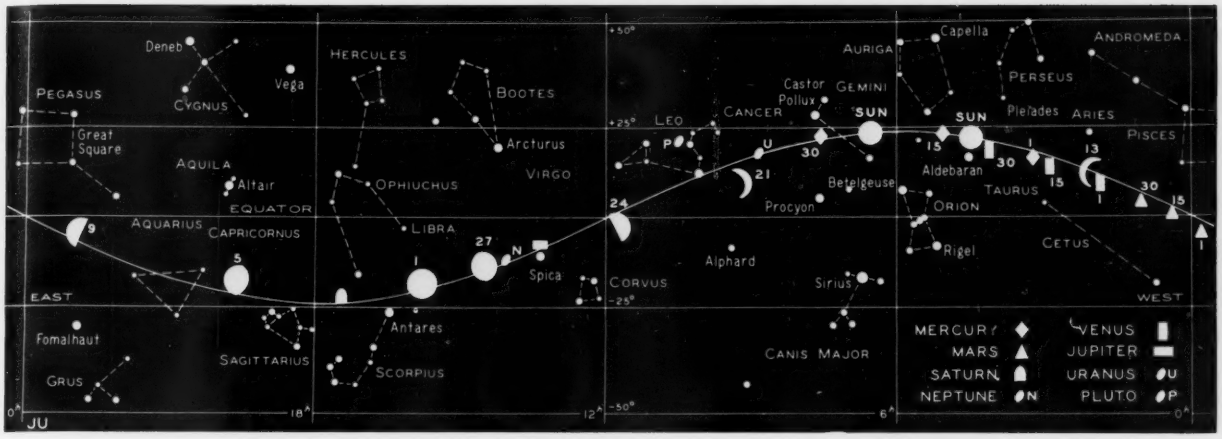
FOR SALE: 16″ Cassegrain, precision made by Ferson Optical Co. Planetary slow-motion control, mounted on new 1956 de luxe truck. May be driven anywhere. Sacrifice for $7,500.00. Should earn this amount in two or three months at good concession. F. W. Manning, 4321 Perrier St., New Orleans 15, La.

INTERESTED in astronomy as a career? *Vocational and Professional Monographs: Astronomy* by Freeman D. Miller describes personal qualifications, scholastic training, and job opportunities. $1.00 postpaid. Send to Box B, *Sky and Telescope,* Harvard Observatory, Cambridge 38, Mass.

ASTROLA 8″, clock drive, no oculars, $200.00. Bruce Covey, 251 Miller Lane, Rochester 17, N. Y.

SCHMIDT'S famous moon map, 25 plates. Printed on 8½″ x 11″ sheets. $1.75 postpaid world-wide. Scientific Book Service, 663 Franklin Ave., Columbus 15, Ohio.

ONE-POWER finder telescope, built-in provision for illuminating crosshair reticle, made by Kodak, government cost $88.00. Limited supply, only $6.00 postpaid. H. Parker Strand, 57 Wyoming Ave., Malden 48, Mass.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month or for other dates shown. All positions are for 0h Universal time on the respective dates.

Mercury is too near the sun in the sky for observation this month; superior conjunction occurs on June 18th.

Venus is a morning star in Aries on the 15th, rising about two hours before the sun. Telescopically, the −3.5-magnitude object shows a gibbous disk 14″ of arc in diameter and 76-per-cent illuminated. The moon will be close to Venus on June 13-14, conjunction occurring at 2:31 UT on the 14th. Venus will be 47′ south as seen from the center of the earth, but observers in Europe and Asia may see the moon occult this bright planet.

Earth arrives at heliocentric longitude 270° at 21:57 UT on June 21st, the time of the solstice. Summer commences in the Northern Hemisphere; winter starts in the Southern.

Mars rises about 1 a.m. local time in midmonth, and is seen in Pisces as a reddish +0.4-magnitude object. In the telescope its 8″ disk will be slightly gibbous.

Jupiter crosses the meridian about sunset in the middle of June, and is the prominent −1.8-magnitude planet in Virgo, about 4° north of Spica. On the 19th it becomes stationary in right ascension; thereafter it resumes eastward motion among the stars.

Saturn arrives at opposition to the sun on the 13th, 840 million miles from the earth. The planet is now at magnitude +0.2, crossing the meridian about midnight local time, and so is visible until dawn. Through a telescope the disk appears 16″.5 in polar diameter, and the rings, which are opened out at their widest during this apparition, are inclined 26°.6 to the line of sight. The northern face of the ring system is seen this year. A diagram of the orbits of Saturn's satellites is shown on page 409.

Uranus on the 15th is a 6th-magnitude planet in Cancer, at right ascension 8h 46m.8, declination +18° 36′ (1958 coordinates). It is visible in binoculars in the western sky during the early evening.

Neptune is in retrograde motion in eastern Virgo. On the 15th this 8th-magnitude planet is at 14h 02m.7, −10° 34′, crossing the meridian at 8:28 p.m. local time.

Artificial satellite observations during dusk this month may be made with the aid of the star chart in this issue; predawn observations will be aided by a September chart. W. H. G.

MINIMA OF ALGOL

June 2, 14:40; 5, 11:29; 8, 8:18; 11, 5:06; 14, 1:55; 16, 22:44; 19, 19:33; 22, 16:21; 25, 13:10; 28, 9:59. July 1, 6:47; 4, 3:36; 7, 0:25; 9, 21:13.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

UNIVERSAL TIME (UT)

TIMES used in Celestial Calendar are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown.

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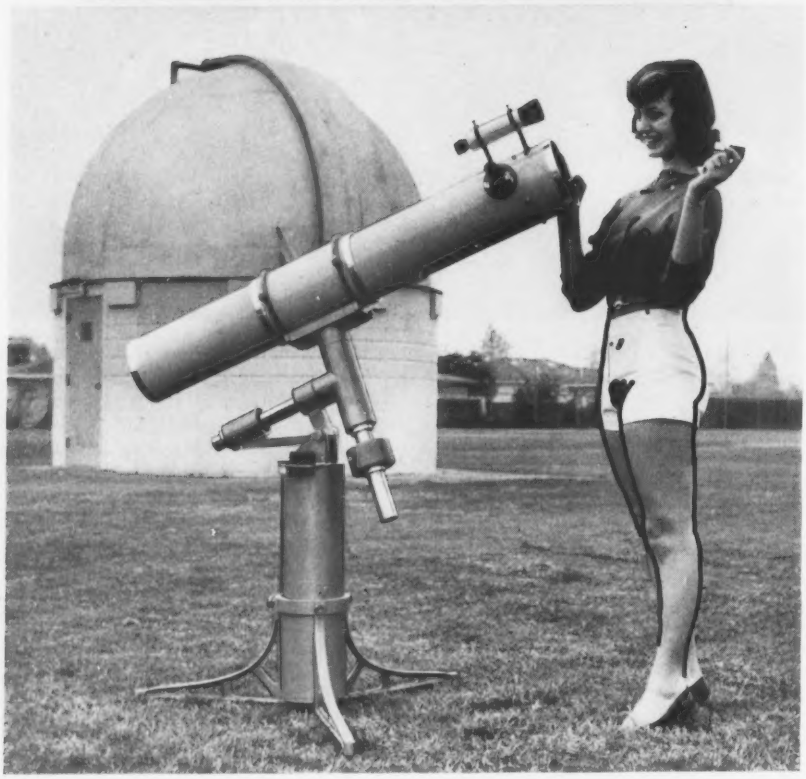

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STARS FOR JUNE

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 22nd of June, respectively. For other dates, add or subtract ½ hour per week.

Thuban, the pole star of about 2750 B.C., is on the meridian at chart time. This 4th-magnitude star is a little more than half way from Polaris, the present pole star, to Alkaid, the end star in the handle of the Big Dipper. It may also be found by going half the distance from Kochab to the stars Mizar and Alcor.

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★ Adjustable equatorial mounting.
★ Clamping in both axes.
★ Steel pedestal with legs that fold up for storage or transportation.
★ Instructions.

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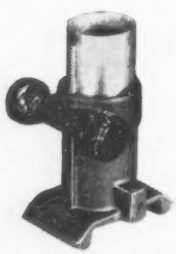

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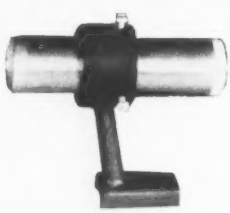

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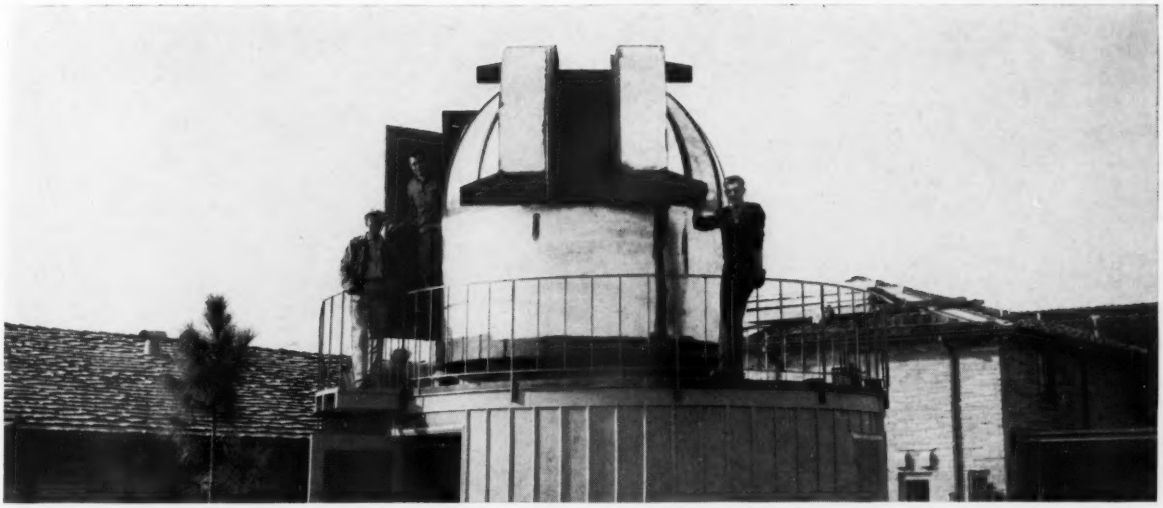

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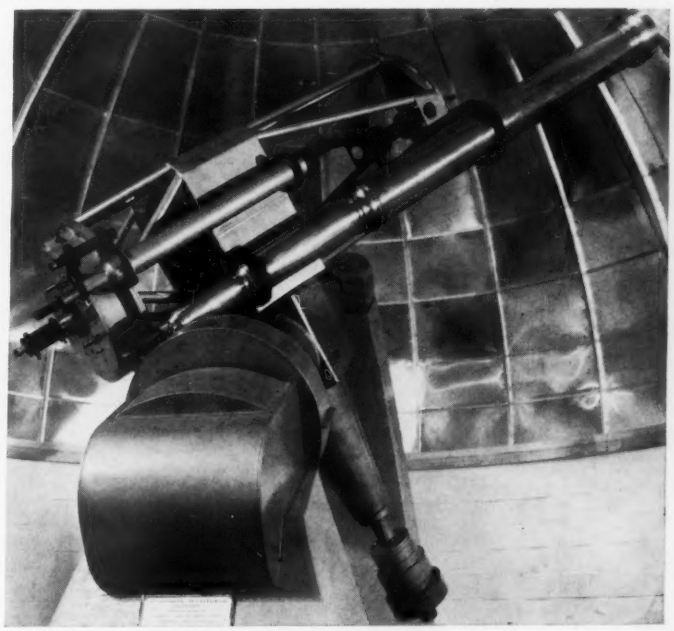

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See pages 428 and 429.

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